Bulletin

OF THE

Geological Society of China

Vol. XXIV June 1944 Nos. 1-2

CONTENTS

PUBLISHED QUARTERLY BY THE SOCIETY

PEHPEI, CHUNGKING, SZECHUAN, CHINA.

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THE GEOLOGICAL SOCIETY OF CHINA

Officers for 1944

Councillors

W. H. Wong, K. Chang, T. F. Hou:	term expires 1944
C. H. Chu, T. K. Huang, J. S. Lee, C. C. Yü, A. W. Grabau, C. S. Lee:	term expires 1945
Y. C. Sun, T. H. Yin, H. S. Wang, C. C. Young, C. Y. Hsieh:	term expires 1946
C. Y. Lee:	term expires 1947

Executive Members:

C. Y. Lee, President,

T. H. Yin, Secretary, T. Y. Hsu†, Assistant Secretary,

T. F. Hou, Treasurer, K. C. Yang and Y. H. Lu, Assistant Treasurers.

Supervisors

T. C. Chow (Executive Member), L. F. Yih, H. T. Lee.

Board of Editors

T. K. Huang, Editor-in-Chief,

T. Y. Hsu†, C. S. Lee, H. C. Chang, W. Y. Chang, S. S. Yoh, C. Y. Hsieh, J. S. Lee.

BULLETIN OF THE GEOLOGICAL SOCIETY OF CHINA
VOL. XXIV, NOS. 1-2, PP. 1-9, JUNE 1944

Proceedings of the Twentieth Annual Meeting

HELD AT KUEIYANG, APRIL 1-3, 1944.

Morning Session of Saturday, April 1.

President Y. C. SUN, in the chair.

The Twentieth Annual Meeting of the Geological Society of China was called to order by the President at 9 a.m. in the Science Building at Kueiyang. The President expressed his satisfaction to see a large number of members and guests attending the meeting and remarked that 1) the number of workers and teachers in geology should be greatly increased, 2) a close coöperation should be established between geological institutions, and 3) the importance of pure research works can never be over-estimated. Addresses of welcome were given by Messrs. T. C. Wu, Governor of Kueichow, T. H. Chang, representing the Ministry of Education, C. Y. Yeh and Y. H. Ou, both of the Kueichow provincial government. The President then called Professor C. Y. Hsieh to give a short report on the preparatory arrangements which led to the success of the Meeting. Thereafter the Secretary, the Treasurer and the Editors submitted their reports.

REPORT OF THE SECRETARY

During the past year three Council Meetings were held, the first in July 4, 1943, the second in February 15, 1944 and the third in March 31, 1944. The minutes were published *in extenso* in Ti-Chih-Luen-Ping.

Late in December 1943 the Society received a letter of goodwill from the Geological Society of America, through Prof. George B. Cressey who came to China as exchange professor sent by the United States Department of State. An official reply of our Society, written March 22, 1944, was brought to New York by one of the Councillors, Dr. C. C. Young, who remitted it to the American Society in May.

We deplore the death of Mr. H. S. Liu and C. Liu, members, and of Professor Charles Schuchert, correspondent member, of the Society.

The present enrollment of the Society is 544 Members, 34 Correspondents, 1 Honorary Member, 104 Associates and 19 Institution Members.

The Council Meeting of July 4, 1943, decided to make the movement to the General Meeting for amendments of Articles 5, 9, 14, 17, 18 and 20 of the constitution of the Society. (The President then submitted the movement to the General Meeting which unanimously accepted it. For the full statement of these amendments, see Ti-Chih-Luen-Ping, Vol. VIII, Nos. 1-6).

The V. K. Ting Memorial Prize will be awarded to Dr. T. K. Huang in recognition of his contributions on the Permian stratigraphy, the Chao's Memorial Fellowship to Mr. W. Y. Chang for his tectonic investigations in Kuangsi and neighbouring provinces, and the Students Fellowship amounting to four thousand dollars will be shared by ten students of the National Southwestern Associated University.

T. H. YIN, *Secretary.*

REPORT OF THE TREASURER

(Fiscal year ended March 17, 1944)

A. Receipts:		
(1) Balance credit of the last fiscal year		31,989.20
(2) Special donations		152,000.00
(3) Special subsidies		87,994.00
(4) Life membership dues		7,350.00
(5) Institution membership dues		13,200.00
(6) Membership dues		1,564.00
(7) Sales of publications		7,895.00
(8) Interest from bank current deposits		22,142.35
	Total	324,134.55
B. Expenditures:		
(1) Printing expenses		154,376.20
(2) Printing paper expenses		76,130.00
(3) Transportation		10,729.00
(4) Geological Exhibition expenses		29,962.80
(5) Excursion expenses		9,090.40
(6) Life membership dues transferred to the Society's Finance Committee		7,350.00
(7) Office expenditures		7,983.11
	Total	295,621.51

Total receipts	324,134.55
Total expenditure	295,621.51
Balance credit	28,513.04

T. F. HOU, *Treasurer.*

REPORT OF THE EDITORS

(A) Bulletin of the Society: Nos. 1-2 and 3-4 of Volume XXII were issued in 1943. The proof-reading of Nos. 1-2 of Volume XXIII has been completed and it will appear soon after the Meeting. Nos. 3-4 will be sent to the press in the near future.

(B) Ti-Chih Luen Ping: The combined numbers 1-6 of Volume VIII, edited by Dr. C. C. Young and Mr. C. J. Peng, were issued in March 1944. Messrs. T. F. Hou and K. C. Yang took part in the proof-reading. Nos. 1-2 of volume IX will soon appear.

C. Y. LEE, *Chief Editor of the Bulletin.*

Following the business reports, the ceremonies for the third awarding of the Ting's Memorial Prize was opened by Professor C. Y. Hsieh, Chairman of the Ting's Memorial Prize Committee, who outlined the important contributions of Dr. T. K. Huang. In the absence of the latter, Dr. T. H. Yin received the diploma of recognition on his behalf.

The first general meeting was adjourned at 12:00.

Afternoon Session of Saturday, April 1.

Dr. Y. C. Sun, in the chair.

The chairman opened the second session at 1:00 p.m. in the lecture room of the Science Building. The following papers were read:

1. J. S. Lee: Geomechanical research of the Nanling.
2. S. S. Yoh: A broad outline on the geology of Kueichou.
3. S. S. Yoh: The geological structure in the environs of Kueiyang.
4. T. H. Yin, N. Chin & I. W. Shen: Outline of the geology of the Tsunyi-Meitan area.
5. T. S. Liu: Geology of North Kueichou.
6. C. S. Lee: The stratigraphy and structure of northern Sinkiang.
7. C. S. Lee: Structural outline of the Great North-West.
8. L. T. Yeh, C. S. Ho & T. C. Tseng: Development of Liupanshan,- its stratigraphical and structural control.
9. P. Misch: On the structural types of E and W Yunnan.
10. W. Y. Chang: Distribution of tin and tungsten deposits in southern China and their relation to tectonic patterns.
11. K. Chern; Note on the Minslde.

The following communications were read by title:

12. T. K. Huang, L. T. Yeh & T. C. Tseng: On major tectonic forms of China with special reference to palaeogeographic development.

13. T. H. Yin, N. Chin & I. W. Shen: Structural lines of the Tsunyi-Meitan area.

14. C. S. Pien & H. H. Lee: The Major structure of the Alashan Range.

15. P. L. Yuan: The emplacement of tin ores in Kochiu district, in Yunnan, in relation to minor structures.

16. Kuota Chan: The Yuehpei System of the Epsilon-type structure.

17. C. C. Chang & C. Y. Jen: Palaeozoic orogenic movement of eastern Sikang.

18. W. K. Kuo: The Post-Tertiary orogenesis of Hueili, Sikang.

19. L. T. Yeh: Significance of structural asymmetry in geosynclinal areas.

20. H. M. Meng: The bearing of tectonic phenomena on Ore-deposition in South China.

21. S. C. Chang: On thrusts.

Evening Session of Saturday, April 1.

Dr. Y. C. Sun, in the chair.

The chairman opened the meeting at 8:00 p.m. The following papers were read:

22. S. Y. Hsia, S. F. Sheng, K. Y. Yen & Y. T. Chang: Some problems in the geology of Kiangsi.

23. W. K. Kuo & C. C. Yeh: Geology of Hueili and Yenpien districts, Sikang.

24. C. C. Chang: Geology of Taliangshan between Szechuan and Sikang.

The following papers were read by title:

25. C. S. Kao: Geology of Fukien.

26. Chingchang Biq & T. L. Hsu: Geology of the Liupanshan region.

27. Y. H. Lu & T. S. Kuo: New observations on the geology of the Central Tsinlingshan.

28. C. H. Lu: Geological reconnaissance in regions on the boundary of Kansu, Tsinghai and Sikang provinces.

29. C. H. Lu & M. S. Chen: A geological section between Suewanpu and Talapei, Chingtaihsien, Kansu.

30. K. L. Fong: Geology of the copper deposits of Lunan district, Yunnan.

31. K. C. Tuan: Preliminary note on the geology of Shihping and Yuankiang, southern Yunnan.

32. P. H. Chang: Geology of Yuhsi-Oshan-Hohsi region, Central Yunnan.

33. P. H. Chang: A geological reconnaissance from Likiang to Wuting, northern Yunnan.

Morning Session of Sunday, April 2.

Dr. Y. C. Sun, in the chair.

Dr. Sun opened the meeting at 8:00 a.m. The following papers were read:

34. C. C. Tien: On the zoning distribution and the age of metallic ore deposits in Hunan.
35. C. Y. Hsieh: Some problems in the study of bauxitic deposits in China.
36. P. Misch: On the facies of the Carboniferous of Kunming region with special reference to the bauxite deposits.
37. C. H. Chen & M. T. Li: Tungsten and tin ores of Machiangyuan, Chianghua, Hunan.
38. T. H. Yin, N. Chin & L. W. Shen: Manganese deposits of Tsunyi.
39. T. S. Liu: The manganese deposit of Tuanhsi, Tsunyihsien.
40. Y. S. Huang & H. Chu: Some remarks on the quicksilver deposits in the Hunan and Kueichou border region.
41. H. Chu: On the genetic types and metallogenetic epoch of the quicksilver deposits of Hunan and Keichou.
42. K. Chern: On the distribution of better-preserved coal seams in a folded field.
43. C. C. Chang: Note on the bituminous coal in Kueichou province.
44. S. T. Yen & C. H. Chen: Geology of the coal-field of Shuicheng and Weining, Kueichou.
45. P. C. Yang & P. L. Yü: The geology of the coal-fields of Tuyung and Tushan districts, Kueichou.
46. W. Y. Chang: A preliminary note on X- and T-shaped joints.
47. L. P. Wu: Flow line structures in the Huashan granite, eastern Kiangsi and its related dikes and veins.

The following communications were read by title:

48. C. J. Peng: Notes on the Kueichou bauxite deposits, with special reference to their vertical variation in nature.
49. S. T. Yen & J. C. Ma: Geology of the bauxitic deposit of Maomaoying, Pingyueh, Kueichou.
50. C. H. Chen & M. T. Li: The lead-zinc deposits of Leitzeshan, Taohsien, Hunan.
51. T. I. Sun: The Manganese deposits of Tsunyi, Kueichou.
52. H. Chu: Structural control of the cinnabar deposits of Panchang, Wuchuan, N. Kueichou.
53. H. C. Wang: A study on the coal resources of Hunan province.
54. T. H. Chow: The lead-zinc deposits of Fulochang, Loping, Kueichou.

55. K. C. Peng: Experiment on the abstraction of a substitute of Canada balsam from native material.

56. L. T. Yeh: Metamorphic geology in the upper Weiho Valley.

Afternoon Session of Sunday, April 2.

Dr. Y. C. Sun, in the chair.

The session was opened by the chairman at 2:00 p.m. The following papers were read:

57. K. Chang: On the mode of occurrence of tin ore of Tachang, Nantan, Kuangsi.

58. K. Chang: Paragenesis of cassiterite and tungsten ores.

59. P. Misch: Observations on Permian and Triassic volcanism of Yunnan.

60. C. C. Chang: A new genetic classification of tungsten deposits in China.

61. C. C. Chang: Genetic classification of antimony ore deposits in China.

62. W. K. Kuo & C. C. Yeh: Note on the granite of Hueili, Sikang and its age.

63. C. S. Lee: The gold deposits of the Altai Mts.

64. C. S. Lee: The iron and coal resources of northern Sinkiang.

65. K. C. Yang & T. C. Ku: On the age of igneous intrusion between Nankiang and Wangtsang, N. Szechuan.

66. C. T. Ma: A brief note on the tungsten and tin deposits of southern Kiangsi.

67. C. T. Ma: Tungsten deposits of Tachishan, Chiennan and the structure of the ore-bearing area.

68. C. H. Chang: Genesis and classification of Kochiu tin deposits, Yunnan and its bearing on tin mining and prospecting.

The following communications were read by title:

69. G. B. Cressey: Natural resources and the future of Asia.

70. H. Y. Ma: Petrology of the Permian volcanic rocks of East and Central Yunnan.

71. P. L. Yuan: The zinc deposits of Laliho in Yunnan.

72. T. H. Chow: The geology of the tin-field of Kochiu.

73. W. W. Loo: The establishment of salt industry and the development of coal mines in Yipinglang district of Yunnan Province.

74. C. C. Chang: A new observation on the gold deposits in southeastern Sikang.

75. C. C. Chang & C. Y. Jen: On the discovery of metamorphosed submarine volcanic rocks between Yuehsi and Hanyuan districts, Sikang, with special reference to their stratigraphic position.

76. C. C. Chang: On the discovery of hematite deposits and oil-bearing semibituminous coal in Mienning district, Sikang.

77. C. C. Chang: Some native copper deposits in Chaochiao, Sikang.

78. W. K. Kuo & C. C. Yeh: The asbestos deposit of Yuchsi, Sikang.

79. C. S. Pien & H. H. Lee: Mineral resources of the Province of Ninghsia.

80. T. K. Huang & Y. C. Cheng: On spontaneous combustion of Jurassic coal seams along the Tienshan.

81. C. H. Lu & M. S. Chen: On the coal and iron deposits of northern Kansu.

82. M. S. Soo: Mineral resources of Szechuan.

83. P. F. Chen: Where is the petroleum of Szechuan?

84. P. P. Chen: The coal-field of Peimiaotze, Yungchang, Central Szechuan.

85. K. C. Peng: Mineralogical analysis of Jurassic sandstones found in the environs of Chungking.

86. K. C. Tsao: Middle Triassic (Anisic) salt deposit of Wuchi, Szechuan.

87. T. I. Sun: The siderite deposits of North Szechuan.

88. C. S. Kao: Mineral resources of Fukien.

89. L. P. Wu: Some problems regarding the tungsten and tin deposits in southern Kiangsi.

90. C. Shangkuan: Kaolin deposits of Yükiang, Kiangsi.

91. Y. H. Lee & C. S. Mo: The tungsten mining industry of T'aishanhsien, Kuangtung.

92. C. S. Mo: Joints in the Chiufeng intrusive and their relation to the wolframite-bearing quartz-veins.

93. Y. S. Wu & K. Chow: The gold-placers of Lishantsun, Tsüanhsien and Huangpeichiang, Hinganhsien, Kuangsi.

94. Y. S. Mu & K. Chow: Gold deposits of Tientung, Tienyang, Tienpao and Hsiangtu districts, Kuangsi.

95. P. H. Chang: The pre-Upper-Sinian mineralization of Yunnan.

96. C. Chen: The titaniferous magnetite deposit of Panchihhua and Taomakan, Yenpien, Sikang.

97. H. M. Meng: Galenostibnite, a new mineral from Huanghweichang, Chungshan, Kuangsi.

98. K. C. Liu: Additional notes on the quicksilver deposits on the Hunan-Kueichou border.

Morning Session of Monday, April 3.

Dr. Y. C. Sun, in the chair.

Dr. Sun opened the meeting at 8:00 a.m. The following papers were read:

99. P. Misch: Observations on the marine Triassic of Yunnan and its relations to the Red Beds.

100. H. C. Chang: Triassic stratigraphy of Tungchuan.

101. H. C. Chang: On the boundary line between Permian and Triassic.

102. Te-You Hsu: On the marine Upper Triassic of China.

103. Te-You Hsu & K. Chen: Revision of the Chingyen Triassic fauna.

104. W. K. Kuo: Red Beds of Hueili, Sikang.

105. S. S. Yoh: On a new genus of rugose coral from the Lower Silurian of North Kweichou.

The following papers were read by title:

106. H. C. Sze: Discrepancies between the chronological testimony of fossil plants and animals with special reference to the stratigraphy of China.

107. Te-You Hsu: Middle Triassic ammonoids of Kueichou.

108. T. H. Yin: Tabulate corals from the Silurian Shihniulan limestone.

109. C. C. Wood: The Silurian stratigraphy of southeastern Szechuan.

110. C. C. Yü: Some Carboniferous Corals from northern Sinkiang.

111. T. C. Tseng: A new simple coral from the Permian limestone of Luipo, Szechuan.

112. S. S. Yoh: On the inner structure of a new species of *Yangtzeella*.

113. T. K. Huang: Red Beds of Sinkiang with special reference to the so-called Kucha Formation.

114. Y. H. Lu: Some microfossils from the Kucha Formation, S Sinkiang.

115. C. C. Chang & C. Y. Jen: The discovery of fossil insects in the Mesozoic rocks of Yuehsi, Sikang.

116. K. C. Tsao: Tentative subdivision of Cretaceous in the southwestern part of the Red Basin.

117. H. C. Wang: On the Weiningian System of southwestern China.

118. H. C. Wang: Preliminary observation on the Carboniferous stratigraphy of Yunnan.

119. H. C. Wang: Outline of the Carboniferous stratigraphy of Yunnan.

120. T. C. Tseng: Middle and Upper Carboniferous stratigraphy of western Kansu.

121. Kuom Chan & C. S. Mo: The Carboniferous coal series of Fuyungshan, Chüchianghsien, Kuangtung.

122. S. H. Li: On the Palaeozoic strata of West Kansu.

123. K. K. Chao: Stratigraphical development in Kuangsi.

124. C. H. Lu & M. S. Chen: The stratigraphy and the orogenic movements of northern Kansu.

125. C. J. Peng: The Sinian stratigraphy of eastern Sikang.

126. C. S. Pien & H. H. Lee: The Sinian and Cambrian stratigraphy of the Alashan region.

127. C. W. Ku: Devonian stratigraphy of Poshi, E. Yunnan.

128. H. C. Szutu: Jurassic coal series of northern Kuangtung.

129. S. H. Li: New Observations on the Nanshan Series.

130. T. Ho, H. C. Wang & H. Y. Hsu: The coal-bearing strata of Central & Eastern Yunnan.

Afternoon Session of Monday, April 3.

Dr. T. H. Yin, in the chair.

The session was opened at 2:00 p.m. in the same lecture room of the Science Building. The following papers were read:

131. C. S. Lee: On the Recent and Quaternary glaciation of NW China.

132. C. Li: The Yunyang Basin of Hupeh and the development of terraces in its neighbourhood.

133. T. C. Sun: Quaternary glaciation in South China.

134. H. Y. Hou: Soils of Kueichou.

135. L. C. Li: Climate of Kueichou.

136. T. H. Ting: Water resources of Anshun and its neighbourhood.

137. Y. C. Hsu: Geomorphology of China.

138. Y. C. Hsu: Preliminary studies on the geomorphology of the Nanling region.

139. K. H. Ku & T. C. Wang: Report on a self-potential survey of the lead-zinc mine at Kuangshanchang, Hueitseh.

The following papers were read by title:

140. T. K. Huang: On the occurrence of Pleistocene glaciation along the northern margin of the Tarim Basin.

141. Y. S. Wu: Notes on Quaternary glaciation in Kuangsi province and its bearing upon placer gold deposits.

142. John Lee: The climatic changes from the Quaternary Ice Age to the Recent.

143. Y. H. Hsiung: Glacial lakes in the neighbourhood of Shouyungchang, Opienhsien, Szechuan.

144. T. Y. H. Ma: Speculations on the Palaeozoic orbit of the earth and the velocity of its revolution.

145. T. S. Liu: Engineering geology along the proposed railroad between Szechuan and Kueichou.

146. H. J. Yang: The geologic structure and the geomorphology of North Kueichou.

147. Y. F. Sze: Geomorphology of the Tsunyi area.

148. K. K. Chao: Origin of the Upper Sikiang.

149. P. F. Chen: On natural bridges.

150. Kuota Chan: Topography of the Upper-Middle Wushui, N Kuangtung.

151. K. H. Ku & T. C. Wang: Report on a self-potential survey of the copper mine at T'angtan, Chiaochiahsien, Yunnan.

152. K. H. Ku & T. C. Wang: Report on a self-potential survey of the copper mine at Losueh, Chiaochiahsien, Yunnan.

153. K. H. Ku & T. C. Wang: Report on a self-potential survey of the pyrite mine at Yilu, Hueitseh, Yunnan.

Three excursions in the vicinity of Kueiyang were organized and effected under the guidance of Dr. S. S. Yoh. For details see Ti Chih Luen Ping.

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VOL. XXIV. NOS. 1-2. PP. 11-14. 1 PL., JUNE 1944

On the Inner Structure of a New Species of *Yangtzeella**

By

S. S. YOH

(Geological Survey of Kueichou)

With 1 Plate

A smooth-shelled brachiopod which occurs very copiously in the middle Ordovician Neichiashan formation of the Upper Yangtze had been repeatedly described as *"Triplecia poloi"* by Martelli in 1901, Pellizzari in 1913, Weller in 1913, and Hayasaka in 1920. It was Kolarova in 1925, who began to doubt the authenticity of its generic determination and had made a series of polished sections from the beak. She then found the presence of spondylium in both valves and showed Martelli's species not at all related to *Triplecia,* but rather closely allied to *Clitambonites, Hemipronites* and *Polytoechia.* Based upon the inner structures, she established the new genus *Yangtzeella,* taking *"Triplecia poloi"* as the genotype. Up to the present only one species is known[1]. Twelve years later, when the writer was engaged to undertake a general geologic mapping-work in the environs of Kueiyang, he chanced to detect a great number of *Yangtzeella*-like shells from an impure limestone formation of middle Ordovician age, near Wutang about 13 km from the east of the city. They are surprisingly well-preserved, not only for the free individuals, but also for the free valves with interiors cleaned by nature. They are here and there scattered on the weathering surface, and can be easily collected by hand-picking. The specimens look at first really like certain European and American species of *Triplecia,* in virtue of

*Received for publication in June 1944.

1. R. Endo described and figured a new species from Shensi under the name of *Yangtzeella reticulata.* This escaped the author's notice. (See R. Endo: The Canadian and Ordovician formations and fossils of South Manchuria, U.S. Nat. Mus. Bull. 164, p. 50, pl. 36, fig. 9, 1932).

their trilobate character of the valves; but on the other hand they have nothing to do with that genus, if the inner structures are more closely examined. The following is a short description:—

Exterior (Figs. 1-3) Outline subquadrate to quadrate, hinge-line straight, little shorter than the greatest width of the shell; lateral profile biconvex, the dorsal valve having much greater convexity. Anterior commisure uniplicate; ventral sulcus very deep and well-defined, commencing from the umbonal region. Dorsal fold high and pronounced throughout, also beginning from the umbonal region. Ventral interarea longer than the dorsal, apsacline; beak slightly curved, umbo inflated, notothyrium open. Surface nearly smooth, marked by concentric growth-lines and distant lamellae, which are crossed by faint and very fine radial ridges. Test fibrous and impunctate.

Ventral interior (Fig. 4) Delthyrial cavity deep; teeth fairly strong and highly projected; dental plates thick, forming a spondylium simplex, which is supported for nearly its entire length by a short and thick median septum, usually bifurcating at its end. On both sides of the median septum are decorated a number of slender radially-arranged low ridges. The posterior portion of the valve is remarkably thickened by adventitious testaceous substance, so that the median septum as well as the radial ridges on its both sides almost become buried, but its anterior border is not influenced by this adventitious matter.

Dorsal interior (Fig. 5) Notothyrial cavity deep; socket deep, brachiophore plates strong. Under the notothyrial cavity produces a papilionaceous muscle platform with an indented frontal margin, which is bisected by a median slit and supported at the back of each self by a lateral septum. The lateral parts of the muscle-platform are free and not united with the brachiophore plates, but only attached to the floor of the notothyrial cavity. A perfect specimen with rather complete papilionaceous muscle platform has recently been sent to the National Geological Survey at Pehpei, Chungking, and is not possible here to be figured. This muscle platform is so fragile that it is always in broken condition and rarely completely preserved. The interior surface of this valve is likewise decorated with a number of radial low ridges. From well-preserved dorsal interiors, cardinalia for the attachment of diductors has been noticed as a simple linear, more or less thickened ridge between brachiophore plates. The posterior portion of the valve is also thickened by the adventitious matter, but far less strong than that of the ventral one.

Distinguishing features. The chief diagnostic characters of *Yangtzeella* are its nearly smooth exterior, *Triplecia*-like outline and profile, ventral spondylium simplex which is supported by a short thick median septum, dorsal plate muscle platform supported by two primary septa, and finally a typical cardinalia situated between the brachiophore plates. One of the interesting features is the great amount of adventitious testaceous substance deposited in the umbonal cavities of the valves, chiefly in the ventral one. The present species differs from the genoholo-type only in the lateral profile, by having more pronounced sulcus, and much higher dorsal fold, both of which commence from the umbonal regions, while the internal characters practically remain the same. But so far the actual form and nature of the spondylium simplex of the ventral valve and the cardinalia as well as the papilionaceous muscle platform of the dorsal valve cannot be shown from the polished sections, whereas these can be clearly observed through the discovery of our free valves with interiors cleaned by nature. This new form will be at present designated as *Yangtzeella kueiyangensis* sp. nov.

Remarks. Owing to the presence of cardinalia and muscle platform supported by two lateral septa in the dorsal valve, *Yangtzeella* was considered to be the closest form of *Clarkella* by the late Prof. Schuchert, and both of which, according to him, should be classified under the family Clarkellidae.

Horizon and localities. This new species occurs in great abundance in a reddish grey impure limestone of middle Ordovician age near a small town, Wutang, about 13 km from the east of Kueiyang. It is also found in the same formation on the northern slope of Machungling about 4 km from the southwest of that town. Coll. S. S. Yoh.

LITERATURE

1. MARTELLI, Allesandro, 1901—Fossili del Siluriano Inferiore dello Schensi (Cina), Bull. d. Soc. Geol. Italiana, vol. 20, (fasc. 1), p. 295-310, pl. 4, figs. 17-22 & 13-16.
2. PELLIZZARI, Giustina, 1913—Fossili Palaeozoici antichi dello Scensi (Cina) Revista Italiana di Palaeontologia, vol. 19. p. 33-48, pl. 1; II, Fossili probabilmente Siluriani, p. 45-47.
3. WELLER, Stuart, 1913—A report on the Ordovician fossils collected in Eastern China in 1903-04, in "Research in China," Carnegie Institute Publications vol. 3, p. 281, pl. 25, figs. 7-9.
4. HAYASAKA, Ichiro, 1920—Palaeozoic Brachiopoda from Japan, Korea and China, p. 59, pl. 22, figs. 1-5. Tokyo Geographical Soc.
5. KOLAROVA, F. N. 1925—The generic status of "*Triplecia*" *poloi*, Bull. Geol. Soc. China, vol. 4, no. 3-4, p. 215-219, 2 figs. & 1 plate.

6. SCHUCHERT, Charles, & COOPER, G. Arthur, 1932—Brachiopod genera of the suborders Orthoidea & Pentameroidea, Mem. of the Peabody Museum of Nat. Hist. vol. 4, pt. 1, p. 157-158, pl. 15, figs. 3, 27-29, 32.

EXPLANATION OF PLATE I.

(All figures are here drawn by Mr. T. H. Chang in natural size)

Fig. 1. Dorsal view of the trilobate shell of *Yangtzeella kueiyangensis* sp. nov.

Fig. 2. Anterior view of the same.

Fig. 3. Lateral view of the same.

Fig. 4. Ventral interior, showing the spondylium simplex (Sp), the median septum with bifurcating end (Ms), and the strong teeth (T).

Fig. 5. Dorsal interior, showing the fragmental muscle platform (Mp), supported by two lateral septa (Ls), Cardinalia (C) between the brachiophore plates and deep sockets (S).

Fig. 6. Transverse section taken about 7 mm below the beak, showing the different inner structures, Sp: ventral spondylium simplex, Ms: median septum, Mp: dorsal muscle platform, Ls: lateral septa. (here the adventitious matter deposited in the umbonal cavities of the valves is not represented.)

Figs. 1—5 belong to the same specimen which is the holotype. All specimens are kept in the Geological Museum, Provincial Institute of Science, Kueiyang (貴陽省立科學館地質陳列室)

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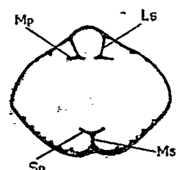

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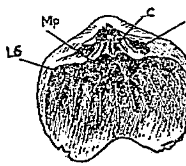

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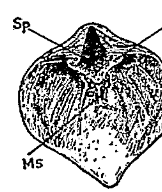

4.

BULLETIN OF THE GEOLOGICAL SOCIETY OF CHINA
VOL. XXIV, NOS. 1-2, PP. 15-20, 1 PL., JUNE 1944

A New *Stauria* from Kueichow*

By

T. H. YIN

(Geological Survey of China)

With 1 Plate.

During a trip to northern Kueichow in 1943, the writer, accompanied by Messrs. N. Chin and I. W. Shen, had the opportunity of securing a rich collection of Silurian corals from the Shihniulan limestone of the Meitan district. Among the compound forms there is one which resembles *Stauria favosa* (Linnaeus) of Gotland. After a closer examination of the numerous slices prepared, it displays some constant differences from Linnaeus' species and eventually belongs to a new form. As the genus *Stauria* remains monotypic for nearly a century long since it was established by Edwards and Haime, and that its known distribution is hitherto confined to North Europe, it seems desirable to give a description of the new form before the entire coral fauna can be worked out.

While studying the material from Meitan, the writer found further specimens of the new form in Mr. S. F. Sheng's collection from a neighbouring district. The following is a list of the known localities:

AB102. Shihniulan limestone, 1.5 kilometers southwest of Somikung[1], Meitanhsien;

AB210. Shihniulan limestone, about one kilometer east of Hsinglungchang[2], Meitanhsien;

Sh115. Shihniulan limestone, a small hill to the immediate southwest of Hunghuayuan[3], Tungtzehsien.

*Received for publication in June 1944.

1. 梭米孔; 2. 興隆場; 3. 紅花園

Thanks to the works of Koch[1], Smith and Ryder[2], and Ting[3], the morphological characters and the mode of axial increase of *Stauria favosa* are fairly well known. This species was originally described from the Upper Silurian—stage *f* of Lindström—of Gotland and subsequently found on the island of Dagö[4], in the vicinity of Reval[5], and as drifts at several localities in East Prussia[6]. Recently Gouwentak[7] reported the occurrence of a *"Staurea"* (=*Stauria*?) associated with *Halysites* in the Silurian rocks of New Guinea.

The writer has to acknowledge Mr. Sheng for allowing him to study fossils in his collection. He also highly appreciates the skillful drawings by Mr. W. T. Chang, which accompany the present paper.

DESCRIPTION.

Stauria prolifera, sp. nov.

Pl. I, Figs. 1-4.

Diagnosis: Corallum partly phaceloid and partly cerioid; corallites 3.5 millimeters in average diameter, each with sixteen to eighteen major septa in the ephebic stage; "Teilungssepten" invariably stouter near the periphery and thinner near the axis; minor septa short, often not conspicuous.

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1. G. v. Koch, 1883. Die ungeschlechtliche Vermehrung (Theilung und Knospung) einiger Palaeozoischen Korallen. Palaeontographica, Bd. 29, p. 329-330, pl. 41, figs. 12-16; pl. 43, fig. 30.

2. S. Smith and T. A. Ryder, 1927. On the structure and development of *Stauria favosa* (Linnaeus). Ann. Mag. Nat. Hist., 9th ser., vol. 20, p. 337-343, textfigs. 1, 2; pl. 9, figs. 1-4.

3. T. H. Ting, 1940. Ueber die Gattung *Stauria* unter besonderer Berücksichtigung der Kreuzsausbildung. Bull. Geol. Soc. China, vol. 20, p. 49-56, textfigs. 1, 2; pl. 1, figs. 1-4.

4. H. Milne Edwards, 1860. Histoire naturelle des coralliaires ou polypiers proprement dits, t. 3, p. 325.

5. E. de Fromentel, 1861. Introduction à l'étude des polypiers fossiles, p. 307.

6. W. Weissermel, 1894. Die Korallen der Silurgeschiebe Ostpreussens und des östlichen Westpreussens. Zeitschr. d. Deutsch. Geol. Ges., Bd. 46, p. 612.

7. C. J. Gouventak, 1939. De exploratie naar goud in Nederlandsch Zuidwest Nieuw-Guinea, Tijdschr. Kon. Nederl. Aardr. Genootsch. Amst. (2) 56, p. 220-235. (Not seen. *Fide* Neues-Jahrb. f. Min., Geol. u. Pal., Referate 3, 1939, Heft 3, p. 404.)

Description: The corallum is at the same time phaceloid and cerioid, none of the examined specimens being entirely phaceloid or entirely cerioid. An incomplete and rather rapidly expanding corallum (AB102e) measures about twenty centimeters across and the whole colony should originally be much larger as can be deduced from the fact that the specimen is broken on all sides. The corallites in close contact with each other have an irregularly polygonal cross section, while the free rim of certain corallites shows either a sinuous curvature or a more or less angular outline. Some of the spaces left by the departing corallites appear as fenestrules of various size and shape, others are irregular and open. Specimens from Hunghuayuan (Sh115) are more phaceloid than those from Meitan (AB102 and AB210), most of the corallites being either free or just in contact, without assuming a decided polygonal outline.

The individual corallites when fully developed, have a diameter ranging from three to four millimeters. In free corallites of oval outline in cross section, the longer diameter may occasionally attain five millimeters.

The thin and continuous epitheca (AB102e) shows longitudinal furrows or septal grooves which seem to be equal in strength for both series of septa. The interseptal ridges are low, rounded, and somewhat wider than the septal grooves. The transverse ornament consists of fine striations, seven or eight in the space of one millimeter, and of irregularly spaced faint bourrelets.

Depth of calices unknown.

The four "Teilungssepten" are longer and stouter than the other major septa. In mature corallites they meet axially and divide the transverse section into four well defined quadrants often subequal in size, but sometimes one or two of the quadrants being markedly smaller. Instead of being dilated at the axial edges, the four septa show a more or less regular diminution of strength from the periphery to the axis and form a kind of patée cross with long limbs, that is, a cross with long wedge-shaped limbs meeting at the axis by their slender edges. "Most of the other major septa terminate freely, but some may abut against a limb of the cross, or against a neighbour, or may even extend to the axis." The minor septa are very short, being one fourth to one third of the length of the major; some are entirely merged in the narrow peripheral stereozone, others rise a little above it.

In the ephebic stage there are sixteen to eighteen major septa, including the four "Teilungssepten." The numbers nineteen and twenty are rarely met with, while corallites with only fifteen or less are considered as still remaining in the neanic stage, though some of them nearly attain full grown size. The distribution among the quadrants varies greatly; in general there are three or four in each quadrant, occasionally only two, and in some cases as many as five are seen in one of the quadrants. Actual examples are shown in the following table:

Corallites	a	a'	c	c'	d	f	f'	g'	3'
Number of major septa (including the Teilungssepten) in corallites	16	17	15	15	17	18	18	16	19
Number of metasepta in each of the four quadrants	3	3	3	2	2	3	3	2	3
	2	2	3	3	4	5	3	4	4
	3	3	4	2	3	2	5	2	3
	4	5	1	4	4	4	3	4	5

The tabulae are more or less closely and regularly spaced. They slope rapidly downward near the periphery and remain more or less horizontal in and near the axial region.

Dissepiments are only observed in one of the four vertical sections so far prepared. They form a discontinuous row of vesicles convex inward at the periphery of one of the four corallites included in that slice (AB102d-I).

The axial increase takes place approximately in the same manner as in *Stauria favosa* described by Smith and Ryder, as we can see from the accompanying figures, but the successive stages of development are not followed.

Remarks: The coral now known under the name of *Stauria favosa* had already been described and figured by Linnaeus[1] prior to 1758, to whom we also owe the specific name[2]. The present generic denomination did not appear until 1850 when Edwards and Haime published the first part of their work on British fossil corals,[3] In the next year, the same authors[4] gave a description and figures of the coral under

1. C. Linnaeus, 1745. Corallia baltica, p. 26, fig. 16 (Not seen. *Fide* G. Lindström, on the "Corallia baltica" of Linnaeus, Kongl. Vetensk-Acad. Ferhandl., 1895, no. 9, p. 633.)

2. C. Linnaeus, 1758. System Naturae, Editio decima, refermata, p. 796. (Not seen. *Fide* Lindström, *loc. cit.*)

3. H. Milne Edwards and J. Haime, 1850. A Monograph of the British fossil corals, pt. 1. Palaeontogr. Soc., 1850, p. lxiv.

4. H. Mile Edwards and J. Haime, 1851. Polypiers fossiles des terrains paléozoïques, p. 316, pl. 1, figs. 1-ld. (Not seen.)

the name of *Stauria astraciformis*, a synonym of *S. favosa;* unfortunately their work of 1851 is not available here and the writer has to rely on copies of their figures in some of the later authors' works[1].

The present species is distinguished from *S. favosa* by 1) the smaller size of its corallites, 2) less numerous major septa, 3) that the four "Teilungssepten" constitute a kind of patée cross instead of a cross of more or less quadrate type as in *S. favosa,* 4) its shorter minor septa, 5) the usual absence of a conspicuous fossula, and 6) its more regularly arranged tabulae.

In the third edition of "A Manual of Palaeontology," Nicholson produced two figures of *S. favosa,* of which one, figure 152, is original and represents a single corallite enlarged ten times. It deviates by some essential characters from all the figures of that species accessible to the writer. This corallite is approximately of the same size as those of *S. prolifera* and shows sixteen major septa. Its minor septa, unusually long, attain a length equal to one half or even two thirds of that of the major septa other than the "Teilungssepten." The last mentioned characteristic prevents us to consider it as a representative of *S. prolifera,* although the size and the number of septa suggest their close affinity. The coral represented by Nicholson's original figure, therefore, deserves a new specific name.

Stauria differs in no other way from *Columnaria* than by the cross formed by the meeting of the cardinal, counter, and alar septa at the axis. Of all species of *Columnaria, C. quadriseptata* Soshkina[2] from the Upper Ludlow of the western slope of the Urals marks a step nearer to *Stauria,* since "only the four septa of the first order, arranged in the form of a cross, reach the center." If the four septa went a little farther and met axially, it would become a *Stauria.*

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1. F. Roemer, 1876. Lethaea Palaeozoica, Atlas, pl. 10, figs. 3a, 3b.
   A. Nicholson, in A. Nicholson and R. Lydekker's "A Manual of Palaeontology", third edit., 1889, p. 273, figs. 151, 152.
   G. Gürich, 1908. Leitfossilien, Lief. 1, p. 37, pl. 10, figs. 5.
   T. W. Vaughan, in Zittel-Eastman's "Text-book of Palaeontology", vol. 1, 1913 (1927), p. 87, textfig. 120.

2. E. Soshkina, 1937. Corals of the Upper Silurian and Lower Devonian of the eastern and western slopes of the Urals. Trav. Inst. Paléozool., t. 6, livr. 4, p. 90, pl. 2, figs. 2, 3.

EXPLANATION OF PLATE I.

Stauria prolifera sp. nov.

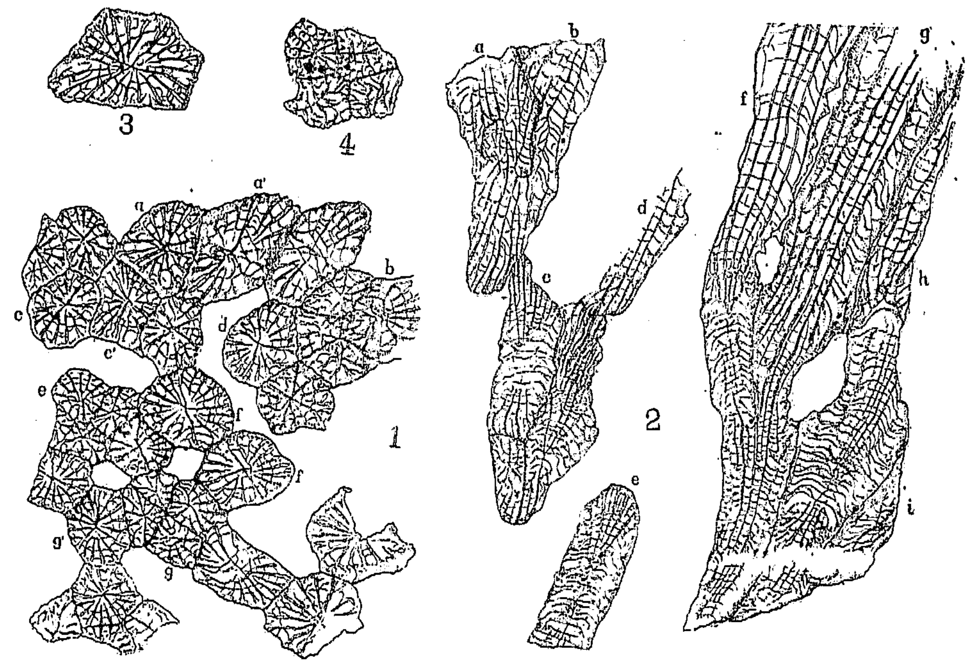
All figures are approximately enlarged five times.

Fig. 1. Transverse section of a group of corallites (AB102c-I) from the Middle Silurian Shihniulan limestone of Somikung (Loc. AB102), Meitan district. Corallites *b*, *e*, and *g*, early hystero-neanic stage; *c* and *c'*, late neanic stage; *a*, *d*, and *f*, early ephebic stage. Holotype.

Fig. 2. Longitudinal section of a few corallites (AB210c-II) from the Shihniulan limestone of Hsinglungchang (Loc. AB210), Meitan district. True median longitudinal section are only obtained near the middle part of the corallites *c*, *f*, and *h*, and near the lower end of *d* and *e*. The hystero-corallites *a* and *b* as well as *f* and *g* are offsprings, through axial increase, of the older corallites at the lower end of each group of the just mentioned hystero-corallites.

Fig. 3. One of the largest individual corallites (AB102d-II) from Somikung.

Fig. 4. A group of four corallites Sh115d-I) in the early hystero-neanic stage from the Shihniulan limestone of Hunghuayuan (Loc. Sh115), Tungtze district.


3
4
a a' b c c' d e f f g g'
1
a b c d e
2
f g h i

BULLETIN OF THE GEOLOGICAL SOCIETY OF CHINA
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The Silurian Rugose Corals of Northern and Eastern Yunnan*

By

H. C. WANG

(National University of Peking)

With 1 Plate.

The material dealt with in this paper was collected by the late Mr. W. Y. Lin[1] from Takuan, Northern Yunnan[2] and by Professor P. Misch from near the Lufengtsun Station[3] of the Yunnan-Indo-China Railway in 1939; and also by various xcursions of the Department of Geology of the National University of Peking to he region of Malung and Kütsing in 1941 and 1942. The bulk of the material of Kütsing occurs in a limestone layer about 100 m above the base of the Middle Silurian, r the Malung formation. A single species was found midway from Chitoutsun[4] o Malung city, in a thin-bedded limestone containing *Pseudoproetus* and *Praecardium*. The specimens obtained from near Lufengtsun also came, according to the personal ommunication of Professor Misch, from the lower part of the Malung formation. The fossil horizon at Takuan, northern Yunnan, characterized by *Pilophyllum*, was not found in the Silurian sequence of eastern Yunnan, where much work on the Silurian stratigraphy has been done. In the following the species identified are arranged tentatively according to their chronological succession.

1. Sayühokou[5], Takuan, northern Yunnan, collected by W. Y. Lin:
   Pilophyllum sayühoense sp. nov.

2. Midway from Chitoutsun to Malung city, collected during an excursion of the Department of Geology of the University:

*Received for publication in June 1944.

1. 林文英先生; 2. 大關; 3. 六豐村; 4. 鷄頭村; 5. 撒魚河口.

Stereoxylodes pseudodianthus (Weissermel) var. *sinense* var. nov.

3. Near the Lufengtsun Station of the Yunnan-Indo-China Railway, collected by P. Misch:

Ketophyllum cf. *crassoseptatum* Wdkd.

4. Yaochiatashan[1], Kütsing, collected by S. H. Sung, H. Y. Ma, K. Y. Lee and the author:

Ketophyllum equitabulatum sp. nov.
K. (Dokophyllum) cf. *lindstroemi* Wdkd.
Cystiphyllum concentricum sp. nov.
Hedstroemophyllum stolleyi Wdkd. var. *sinense* var. nov.
Hed. conicum sp. nov.
Hed. gyalophylloides sp. nov.
Kyphophyllum primaevum sp. nov.

These assemblages show much resemblance to those found in the Gotlandian System of Gotland and in the shell facies of the Silurian of England. The lowest coral horizon, the Yaochiatashan horizon of Kütsing, characterized by abundant *Hedstroemophyllum* and *Ketophyllum*, is evidently comparable with the *Lindstroemia*-Stufe of Wedekind, or the lower part of the Middle Gotlandian. *Stereoxylodes pseudodianthus*, found midway from Chitoutsun to Malung city, is a frequent form n the upper part of the Wenlock Limestone of England. The Sayühokou horizon of northern Yunnan with *Pilophyllum* can evidently be compared with the *Pilophyllum*-Stufe of Wedekind, or the Upper Gotlandian.

All these horizons occur in the Malung formation which is the exact equivalent f the Salopian, or the Middle Silurian of Europe. That the shale facies of the Silurian of South China begins with Salopian has already been emphasized by Pro-essor Y. C. Sun. This conception is again confirmed by the study of its rugose coral faunas.

In acknowledgment, the author should like to express his sincere thanks to Professor Y. C. Sun for his supervision and valuable suggestions, to Professor P. Misch, Messrs. W. Y. Lin, S. H. Sung, H. Y. Ma and K. Y. Lee for their generosity in furnishing him their interesting and valuable material.

1. 岳家大山.

DESCRIPTION OF SPECIES

Genus *Pilophyllum* Wedekind 1926

Genotype, *Pilophyllum keyserlingi* Wdkd. 1926

Diagnosis—Subcylindric simple rugosa with a solid or a lonsdaloid mantle zone of discontinuous septa; with convex and vesicular tabulae occasionally differentiated into an axial and periaxial series; and with short and trabeculate minor septa.

Remarks—Wedekind described *Pilophyllum* in 1926, considering it as a descendent of *Kodonophyllum*, in which the solid mantle zone splits up completely or incompletely into cysts. In the group of *Pilophyllum weissermeli* Wdkd., the tabularium is not differentiated, the tabulae are without median notch and the axial ends of the major septa are enrolled. Through these characters this group differs from *Kyphophyllum* Wdkd. which has also a lonsdaloid mantle zone and convex tabulae. Another group, the group of *Pilophyllum (Aulacophyllum) munthei*, has undifferentiated flat tabulae, but the tabulae are marked with median notch and the major septa often reach the epitheca. Though Wedekind considers that *Kyphophyllum* and *Pilophyllum* come from different trends, the former being a descendent of *Streptelasma*, the latter that of *Pholidophyllum*, it is not impossible that the three groups, the group of *Pil. weissermeli*, the group of *Kyphophyllum* and the group of *Pil. munthei*, represent closely related forms belonging to one and the same trend of development.

Pilophyllum sayühoense sp. nov.

Plate I, fig. 1a-b.

Holotype—Cat. No. S4201-2, Department of Geology, Nat. SW Assoc. Univ. Middle Silurian, Takuan, northern Yunnan, Coll. W. Y. Lin.

Diagnosis—*Pilophyllum* with major septa nearly reaching the periphery and nrolled in the axial portion, with a peripheral stereozone, with axial, concave vesicular abulae, and periaxial outwardly inclined tabellae.

Description—Corallum cylindric, with thick epitheca, 22 mm in diameter and more than 40 mm in length. Within the solid peripheral zone is a lonsdaloid zone. There are 34 major septa, mostly reaching the periphery. The axial ends of the major septa are enrolled in one direction. In the lonsdaloid zone the major septa are occasionally discontinuous, and the minor septa trabeculate. This lonsdaloid zone is well delimited by an inner wall and is composed of large, steeply inclined elongate cysts partly thickened with stereoplasm. The periaxial zone of outwardly inclined tabellae has a width equal to that of the mantle zone and abuts against the inner wall. There is no distinct boundary between this and the axial series with convex, close, vesicular tabulae.

REMARKS—Our form resembles the genotype (*Pilophyllum keyserlingi*) in the axial enrolling of the major septa and in the vesiculate tabulae, but differs therefrom in the lonsdaloid, instead of a solid, mantle zone. It is probably most closely related to *Pilophyllum progressum* Wdkd. which it resembles in every respect in interseptal structure. In the well differentiated tabularium, it approaches *Kyphophyllum lindstroemi*, but the latter has radial major septa and globose instead of cystose dissepiments.

GENUS *Entelophyllum* WEDEKIND 1926

SUBGENUS *Stereoxylodes* subg. nov.

Subgenotype; *Cyathophyllum pseudodianthus* Weissermel

DIAGNOSIS—Cylindric, phacelloid or simple rugosa with long major septa reaching or nearly reaching the axis, strongly dilated and sometimes carinate in the peripheral portion to form a stereozone; with numerous suppressed dissepiments and with tabulae differentiated into an axial and concave periaxial series.

REMARKS—Smith and Tremberth described in 1929 *Xylodes articularus* (based on *Madreporites articulatus* Walenburg) and *Kodonophyllum truncatum* (based on *Madrepora truncata* Linnaeus). A third species, *Xylodes pseudodianthus*, (based on *Cyathophyllum pseudodianthus* Weissermel) was notified and was considered as forming a link between the two former species. In 1927 Wedekind established the genus *Entelophyllum* under his Family Kyphophyllidae and listed *Madreporites articulatus* as *E. articulatum*. Hill (1940) recognized the priority of Wedekind's generic name and listed several species of *Entelophyllum* (*E. articulatum*, *E. pseudodianthus* and *E. rugosum*) in addition to her two new Australian species. However, according to the diagnosis given by Smith and Tremberth (1929, *Xylodes*) and by Hill (1940, *Entelophyllum*), *Entelophyllum* includes corals with long, thin, typically not modified septa and though sometimes carinate, never dilate so as to form a conspicuous peripheral stereozone. *Cyathophyllum pseudodianthus* Weissermel with strongly dilated and carinate septa to form a peripheral stereozone is evidently distinct from the genotype of *Entelophyllum*. Here the subgeneric name *Stereoxylodes* is introduced to include those entelophyllids characterized by dilated and carinate septa, and Weissermel's species is chosen as the subgenolectotype. With this point of view *Entelophyllum assense* Hill (1940) stands midway between the true *Entelophyllum* and *Stereoxylodes*.

Stereoxylodes pseudodianthus (Weissermel)

var. *sinense* var. nov.

Plate I, fig. 2a-b.

Holotype, Cat. No. S4211-3, Department of Geology, Nat. SW Assoc. Univ. Middle Silurian, Malung, eastern Yunnan, Coll. Univ. excursion.

Diagnosis—*Stereoxylodes pseudodianthus* with strongly dilated major septa in the peripheral stereozone, with very short minor septa and with an interseptal structure much like that of *Entelophyllum articulatum*.

Description—Corallum 14 mm in diameter and more than 20 mm in length. There are 34 major septa nearly reaching the axis. The peripheral stereozone formed by the lateral contiguity of septa has a width 1/3 that of the radius. The axial ends of the major septa are attenuated and show an enrolling tendency. The minor septa are as thick as the major ones, but seldom extend beyond the peripheral zone. In the longitudinal as well as in the transverse section the three zones, the outermost stereozone of contiguous septa and suppressed dissepiments, the periaxial zone of flat-lying tabellae and the axial zone of complete, close and slightly concave tabulae, are distinct. There are 21 tabulae in a vertical distance of 6 mm. Another specimen belonging evidently to the same variety, which is only known by the transverse section, shows strongly carinate septa.

Remarks—This form differs from (*Stereoxylodes pseudodianthus*) only in the less marked axial structure and in the less concave periaxial tabellae. In the conspicuous peripheral stereozone and the strong dilatation of the septa, and in the indistinctly differentiated tabularium, it reminds much of the Devonian genus *Temnophyllum* Walther.

Genus *Kyphophyllum* Wedekind 1926

Genotype *Kyphophyllum lindstroemi* Wedekind 1926

Diagnosis—Simple or composite rugosa with a more or less developed peripheral cystose zone, with convex tabulae, with complete major septa reaching the axis and trabeculate minor septa confined to the peripheral portion.

REMARKS—This genus was established by Wedekind in 1926 as the type genus of his Kyphophyllidae. The important characters lie in the spinose minor septa, the cystose peripheral zone and the convex tabulae reminding those of *Streptelasma*. On this ground Wedekind considered that Kyphophyllidae is a descendent of Streptelasmidae.

Kyphophyllum primaevum sp. nov.

Plate I, fig. 3a-b.

Holotype—Cat. No. S4221-3, Department of Geology, Nat. Assoc. SW Univ. Middle Silurian, Yaochiatashan, Kütsing, eastern Yunnan. Coll. Department excursion.

DIAGNOSIS—Small conical *Kyphophyllum* with major septa mostly reaching the epitheca, with a narrow cystose peripheral zone only in the distal end, and with vesicular tabulae in the tabularium.

DESCRIPTION—Conical corallum measuring 13 mm in diameter and 16 mm in length. There are 26 major septa in a section measuring 6 mm and 31 in one measuring 12 mm. A faint cardinal fossula is developed in the proximal end, but becomes obscure in the distal portion. The major septa reach the axis and are slightly enrolled. In the proximal transverse section the minor septa are extremely short, contiguous with the major ones to form a peripheral stereozone. In the distal end there are 2-4 rows of peripheral cysts upon which are mounted septal trabeculae (minor septa). The tabulae are cystose and incomplete, convex in the axial portion, sloping down periaxially, then turning upward again and grading into the peripheral cysts.

REMARKS—It is interesting to note that this species has a typical *Streptelasma*-structure in the proximal portion of the corallum; but a narrow peripheral cystose zone, in which the major septa may yet be complete but the minor ones are spinular, is developed in the adult stage. With the viewpoint of the development of a peripheral cystose zone, it is dimorphous and transitional between *Streptelasma* and *Kyphophyllum*. This seems to be consistent with Wedekind's opinion that *Kyphophyllum* is developed from *Streptelasma*.

GENUS *Ketophyllum* WEDEKIND 1926

Genotype *Ketophyllum stanley-smithi* Wedekind 1926

DIAGNOSIS—Conical or subcylindric simple rugosa usually with cup-shaped calyx, with discrete or occasionally contiguous septal spines, with large, steeply inclined cysts in the mantle and close, subhorizontal tabulae in the axial zone.

REMARKS—Wedekind established the genera *Ketophyllum* and *Dokophyllum* in 1926 under his family Omphymatidae. According to him the chief difference between these two genera lies in that *Ketophyllum* has a rather wide mantle zone, more or less contiguous septal spines and a well-developed septal fossula, while *Dokophyllum* has typically discrete septal spines, has a tabular fossula in most cases, and may be diaphragmatophor. However, *Ketophyllum conicum* and *K. cylindricum* also show typical discrete septal spines, and *K. annulatum* has a distinct tabular fossula. Again, in the proximal section of *K. richteri*, the mantle zone is not developed and is therefore also diaphragmatophor. For these reasons the author prefers to consider *Dokophyllum* as described by Wedekind as cogeneric with his *Ketophyllum*.

Ketophyllum equitabulatum sp. nov.

Plate I, fig. 4a-b.

Holotype—Cat. No. S4231-2, Department of Geology, Nat. SW Assoc. Univ. Middle Silurian, Yaochiatashan, Kütsing, eastern Yunnan. Coll. Department excursion.

DIAGNOSIS—Slightly curved conical or subcylindric *Ketophyllum* with wide, close, quidistant tabulae sloping down in the border parts and with very large irregular cysts in the mantle zone.

DESCRIPTION—This species is represented by several specimens the largest of which measures 14 mm in diameter. The holotype has thick epitheca, 2-rows of peripheral cysts in the proximal, and 4-5 rows in the distal transverse section. The tabulae are complete, horizontal, close, sloping down in the border portions and are grouped into series. There are 26 tabulae in a vertical distance of 6 mm. The peripheral cysts are mounted by numerous small, short, typically discrete spines. Sometimes one single cyst may surround nearly one half of the whole periphery.

REMARKS—In the irregular form of the peripheral cysts our species resembles *Ketophyllum involutum* Wdkd., but the latter has much less tabulae set at different distances. The equidistant disposition of the tabulae is peculiar to and only known in our new species.

Ketophyllum cf. *crassoseptatum* Wdkd.

DESCRIPTION—This specimen was collected by Professor P. Misch from near Lufengtsun. It is embedded in a block of limestone, thus the external form and the epithecal characters are not available to observation. One transverse section near the calyx was made which reveals much the resemblance to *Ketophyllum crassoseptatum* Wdkd.

Ketophyllum (Dokophyllum) cf. *lindstroemi* Wdkd.

DESCRIPTION—Corrallum subcylindric, diameter measuring 21 mm, contracting suddenly in the proximal end, faintly annulate, with thick epitheca and a typical cup-calyx. The cystose mantle zone is half as wide as the radius, composed of highly arched elongate cysts partly thickened with stereoplasm. The tabulae are complete, horizontal, arranged in groups and mounted with septal remains. There are 25 tabulae in a vertical distance of 7 mm. This specimen is only known by the longitudinal section. The faint annulate external form, the cup-shaped calyx, the wide mantle zone and the dentate character of the septa of our form lead us to compare it with *Dokophyllum lindstroemi* Wdkd.

GENUS *Hedstroemophyllum* WEDEKIND, 1926

Genotype, here chosen, *Hedstroemophyllum weissermeli* Wdkd. 1926

DIAGNOSIS—Elongate, conical simple rugosa with sharp-bordered funnel-calyx; interseptal structure cystiphor, composed of large flat cysts in the axial portion. Septal spines numerous, forming radial rows, continuous periodically and cutting through the cysts.

REMARKS—In septal development *Hedstroemophyllum* is transitional between *Cystiphyllum* Lonsdale which has trabecular septal spines never cutting through more than one cyst and *Gyalophyllum* Wedekind which has wholly contiguous septal spines strongly thickened with stereoplasm to form 'Septalleisten.' Wedekind recognized two groups of the genus *Hedstroemophyllum*, an advanced group of *H. aticulum* with large, flat central cysts and thus more or less pleonophor, and the primitive group of *H. tenue* with central cysts approaching the peripheral ones in size. In 1926 Wedekind established another genus, *Holmophyllum*, considering it as a descendent of his *Pholidophyllum*. *Holmophyllum* has a septal structure identical with that of *Hedtroemophyllum*; but interseptally, it has rather globose peripheral cysts and distinct flat tabular plates in the central part, and is therefore typically pleonophor.

Hedstroemophyllum conicum sp. nov.

Plate I, fig. 5a-b.

Holotype—Cat. No. S4241-3, Department of Geology, Nat. SW Assoc. Univ. Middle Silurian, Yaochiatashan, Kütsing, eastern Yunnan. Coll. Department excursion.

Diagnosis—Small, annulate, asymmetrically conical *Hedstroemophyllum*, with large, flat, partly thickened central cysts, with radial rows of discontinuous septal spines which may be partly contiguous near the periphery, and with a central zone free of septal remains.

Description—This species is represented by several specimens measuring in average 20 mm in diameter and 22 mm in length. The central zone, free of septal remains, has a width 1/3 to 1/4 that of the lumen and is usually eccentric in position. In transverse section cut near the calyx the septa are represented by numerous radial rows, each row being composed of numerous discontinuous, equisized blunt septal spines. There are 90-95 septal rows in sections measuring about 20 mm. in diameter; the major rows and the minor rows are in most cases discernible from each other. In the proximal sections stereoplasmal filling of the interseptal loculi is frequent; but the contiguous thickening of the septal spines is only confined to the peripheral portion. The longitudinal section shows a wide central zone of large flat cysts periodically filled with stereoplasm to form successive floors, forming a series of cones imposed one upon another. These cones correspond to the sharp annulations of the corallum.

Remarks—In the wide central zone of large flat cysts and in the conical external form, our species bears a resemblance to *Hed. articulatum*. In the separate point-like septal remains it resembles *Hed. weissermeli*, but the latter has a quite different interseptal structure. The important character of our species lies in its short eccentric conical corallum and in the structure of successive cones imposed one upon another.

Hedstroemophyllum gyalophylloides sp. nov.

Plate I, fig. 6a-b.

Holotype—Cat. No. S4251-3, Department of Geology, Nat. SW. Assoc. Univ. Middle Silurian, Yaochiatashan, Kütsing, eastern Yunnan. Coll. Department excursion.

Diagnosis—Small conical *Hedstroemophyllum* in which the structure of successive ones is distinct and in which the contiguous thickening of the proximal ends of the epta is almost complete.

Description—This species is represented by several small specimens measuring 0-13 mm in diameter. In the longitudinal section it resembles *H. conicum* in the wide central zone and in the successive cone floors strengthened with stereoplasm, but the central cysts are often unusually large and are highly convex. In the transverse section there are often two or three concentric rings of contiguous septa. Each ring is composed of rather long septal spines entirely contiguous in their proximal ends but separate in their inner portion. In the almost complete contiguity of the proximal portion of the septal spines and in the strong stereoplasmal thickening of the central cysts our species approaches *Gyalophyllum* Wdkd. and may eventually be considered as a transitional form between *Hedstroemophyllum* and *Gyalophyllum*.

Hedstroemophyllum stolleyi Wdkd. var. *sinense* var. nov.

Plate I, fig. 7a-b.

Holotype—Cat. No. S4261-3, Department of Geology, Nat. SW Assoc. Univ. Middle Silurian, Yaochiatashan, Kütsing, eastern Yunnan. Coll. Department excursion.

Diagnosis—Curved, annulate subcylindric *Hedstroemophyllum* with rather long, partly contiguous septa; spines, with a central zone free of septa and composed of large convex cysts periodically thickened with stereoplasm.

Description—Corallum subcylindric, 18 mm in diameter, strongly annulate and moderately curved. There is a narrow peripheral stereozone formed by the contiguous thickening of the septal spines. In the intermediate portion of the lumen the septal spines are numerous but separate from each other. There are 33 major septa, mostly complete but some of them discontinuous, in a section measuring 17 mm in diameter. The minor septa are typically short, trabeculate, but some may also cut through more than one cyst. The central zone free of septal remains has a width less than 1/3 that of the lumen. It is composed of large, horizontally disposed convex tabular plates which are periodically thickened with stereoplasm.

Remarks—In the external form and in the interseptal structure our variety is dentical with *Hedstroemophyllum strolleyi* Wdkd. It differs therefrom only in the more complete major septal spines and in the periodical thickening of the central cyst floors.

Genus *Cystiphyllum* Londsdale 1829

Genotype *Cystiphyllum siluriense* Lonsdale 1829

Diagnosis—Simple cylindric or subcylindric rugosa in which the vertical structures are reduced to separate spines and the whole lumen is filled with vesicular cysts, which are steep and close in the mantle and flat, large in the central zone.

Cystiphyllum concentricum sp. nov.

Plate I, fig. 8a-b.

Holotype—Cat. No. S4271-3, Department of Geology, Nat. SW Assoc. Univ. Middle Silurian. Yaochiatashan. Kütsing, eastern Yunnan. Coll. Department excursion.

DIAGNOSIS—Horn-shaped *Cystiphyllum* with a wide mantle zone of firstly convex, then steeply inclined and elongate cysts, and with a narrow tabular zone of flat, wide-apart tabular plates. Septal remains are entirely absent.

DESCRIPTION—Corallum conical, slightly curved, 12 mm in diameter. In the mantle zone, which has a width 4/5 that of the radius of the corallum, every cyst is first highly convex upwards, then suddenly steeply inclined towards the axis and much elongated. Thus in the transverse section the peripheral rings of cysts, corresponding to the highly convex portion of the cysts, appear in irregular oval sections. The intermediate rings corresponding to the steeply inclined portion often contain cysts assuming a flat or even a straight outline abutting against each other at acute angles. The narrow central zone is composed of flat-lying, wide-apart irregular tabular plates.

REMARKS—The author has not seen any other Silurian cystiphyllids hitherto described which can be compared with our new species. The only species comparable with it is probably the Middle Devonian *Cystiphyllum macrocystis* Schlüter. These two species coincide in their external form, in their inclined, elongate peripheral cysts and in their very narrow tabular zone. But the conspicuous upturning of the upper portion of the peripheral cysts, which is a prominent feature of our new species, is indistinct in *C. macrocystis*.

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EXPLANATION OF PLATE I

1. *Pilophyllum sayühoense* sp. nov.
   1a. Transverse section x 3/2. Holotype, Cat. No. S4201.
   1b. Longitudinal section x 3/2. Holotype, Cat. No. S4203.

2. *Stereoxylodes pseudodianthus* var. *sinense* var. nov.
   2a. Transverse section x 2. Holotype, Cat. No. S4211.
   2b. Longitudinal section x 2. Holotype, Cat. No. S4213.

3. *Kyphophyllum primaevum* sp. nov.
   3a. Transverse section x 2. Holotype, Cat. No. S4221.
   3b. Longitudinal section x 2. Holotype, Cat. No. S4222.

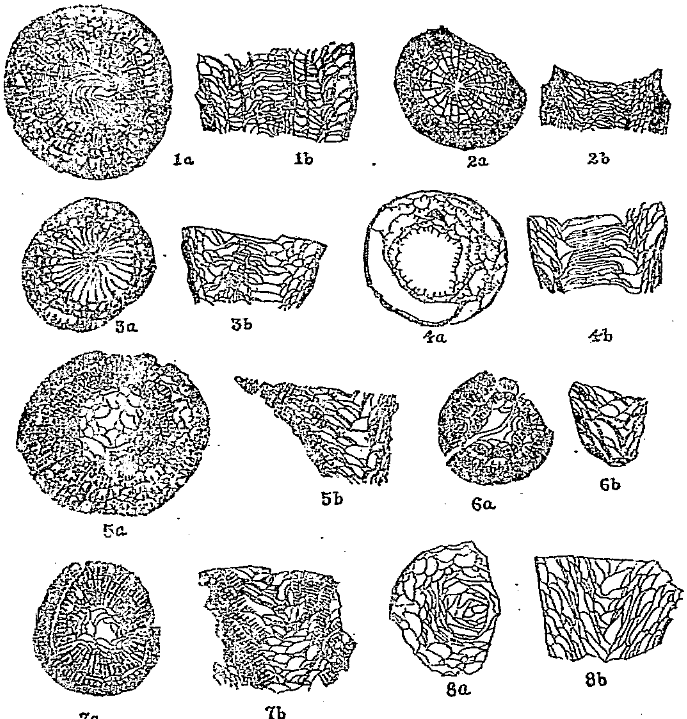
4. *Ketophyllum equitabulatum* sp. nov.
   4a. Transverse section x 2. Holotype, Cat. No. S4231.
   4b. Longitudinal section x 2. Holotype. Cat. No. S4233.

5. *Hedstroemophyllum conicum* sp. nov.
   5a. Transverse section x 2. Holotype, Cat. No. S4241.
   5b. Longitudinal section x 2. Holotype, Cat. No. S4243.

6. *Hedstroemophyllum gyalophylloides* sp. nov.
   6a. Transverse section x 2. Holotype, Cat. No. S4251.
   6b. Longitudinal section x 2. Holotype, Cat. No. S4252.

7. *Hedstroemophyllum stolleyi* var. *sinense* var. nov.
   7a. Transverse section x 2. Holotype, Cat. No. S4261.
   7b. Longitudinal section x 2. Holotype, Cat. No. S4262.

8. *Cystiphyllum concentricum* sp. nov.
   8a. Transverse section x 3/2. Holotype, Cat. No. S4271.
   8b. Longitudinal section x 3/2. Holotype, Cat. No. S4273.



Drawn by Author

BULLETIN OF THE GEOLOGICAL SOCIETY OF CHINA
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The Charophyta from the Kucha Formation near Kucha, Sinkiang*.

By

LU YEN-HAO

(Geological Survey of China)

With 1 Plate

The fossil Charophyta collected by Messrs. T. K. Huang, C. C. Young, Y. C. Cheng and T. C. Chow from near Kucha, S Sinkiang, consist of a very large number of calcified oogonia and a few fragments of undeterminable vegetative parts. The fossiliferous horizon belongs to the lower part of the Kucha Formation of Norin, which is strongly tilted with a dip angle of about 74°, hence the oogonia were laterally flattened or else crushed into spheroids, but in the majority of cases they are preserved in natural state, giving rise to a circular cross-section along the equator. Moreover, the degree of calcification of the spiral-cells may differ in the same species and even in the same individual, resulting in marked variations both in their shape and in the nature of the sutures.

Three types of oogonia are recognized and all of them are described as new species. Consequently they furnish no precise information concerning the age of that part of the Kucha Formation in which they occur. Both Norin and Huang are inclined to consider it as early Tertiary, to which proposition our palaeontological study has not the least objection. For fuller discussion on the stratigraphy the reader is referred to Huang's contribution.

*Received for publication in June 1944.

DESCRIPTION OF SPECIES

Family Characeae

Genus *Chara* Vaillant, 1719.

Chara sinkiangensis sp. nov.

Pl. I, Figs. 1a-c.

DIAGNOSIS:—Oogonium large, obovoid in shape, swollen at the middle, with the sides converging rapidly from the greatest diameter to the somewhat obtuse base and gradually to the truncate, slightly depressed and broad apex. Length ranging from 1125 μ to 1280μ, breadth 935—1060μ. Spiral-cells showing 8-9 convolutions, smooth, convex, with the sutures in broad and deep furrows. Width of these cells uniform, measuring about 130-160μ. Equatorial angle about 16-18°. Tips of the spiral-cells at the apex slightly depressed, giving rise to a remarkable rosette.

REMARKS:—*Chara sinkiangensis* is the most common type of oogônium found in the Kucha Formation, and approximately eight out of every ten specimens examined belong to it. This species is characterized by its shape and by the truncate, broad apex. The colour is dark brown or brownish black. Variations are noted in the degree of calcification: completely calcified portions show convex spirals whereas the spirals in partially calcified portions appear slightly concave. In most specimens, however, a partial calcification around the base of the oogônium is developed, giving rise to the grooved nature of the spirals and at the same time the sutures in that region are usually situated in distinct ridges. This new species is similar to *Chara meriani* Unger from the Miocene and Oligocene of Europe in the size and shape, but is distinguished from the latter by its truncate and very broad apex.

Chara huangi sp. nov.

Pl. I, Figs. 2a-c.

DIAGNOSIS:—Oogonium large, elongate-truncate ovoid in shape, measuring 1000-1020 μ in length and 787-898μ in width, with sides converging regularly from the greatest diameter at mid-height to a pointed, more or less projecting base and in turn converging very gradually to the sharply truncate apex. Spiral-cells showing 9 convolutions and with an equatorial angle usually from 8° to 10°. Width of the spiral-cells about 125-137 μ. Apex very abroad, somewhat depressed, possessing a well-defined rosette.

REMARKS:—This form is closely allied to the preceding species, but differs from it in the broader apex, the rather low equatorial angle and the comparatively small size. The species is named after Dr. T. K. Huang.

Chara youngi sp. nov.

Pl. I, Figs. 3a-c.

DIAGNOSIS:—Oogonium of medium size, measuring about 800-875 μ in length and 640-655 μ. in breadth, elongate-ellipsoid in shape, tapering towards both extremities. Spiral-cells smooth, showing 8-9 convolutions, measuring about 105-125 μ in width. Equatorial angle about 14°. Tips pronounced, standing out as a distinct rosette. Spiral-cells either convex throughout or slightly concave or else flattened on the lower half portion near the base.

REMARKS:—This form somewhat resembles *C. helicteres* Brongniart from Palaeocene to Miocene of Europe and from Kateru inter-trappeans of India, but differs widely from it in the elongated shape and in the much smaller size. This species is named in honor of Dr. C. C. Young.

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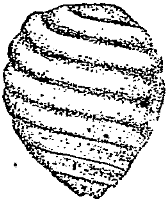
EXPLANATION OF PLATE I.

Camera lucida drawings, all specimens enlarged 32 diameters.

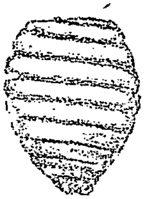
(a, lateral, b, apical and c, basal views)

1. *Chara sinkiangensis* sp. nov., Holotype.
2. *Chara huangi* sp. nov., Holotype.
3. *Chara youngi* sp. nov., Holotype.

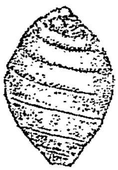
All the specimens above described are kept in the Laboratory of Paleontology, Geological Survey of China.

1a 1c

2a 2b 2c

3a 3b 3c

BULLETIN OF THE GEOLOGICAL SOCIETY OF CHINA
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Middle and Upper Carboniferous Stratigraphy of Western Kansu*

By

T. C. TSENG

(Geological Survey of China)

With 2 Plates

I. INTRODUCTION

Both Middle and Upper Carboniferous rocks are well developed in Western Kansu and were investigated by Loczy [19], Obrutchev [21], Yuan [31, 32], and Sun [25]. Though the faunas from these rocks have been studied in some detail by Loczy, Chao, Lee and others, their stratigraphic succession and the correlation of fossil horizons found in them in different localities yet remain to be established. In 1941-942, T. K. Huang and party, of which the writer was a member, made reconnaissance surveys in western Kansu and collected late Carboniferous fossils from a number of localities. This material, chiefly consisting of brachiopods, is studied by the writer whose result with regard to stratigraphy is summarized in the present paper.

The writer takes this opportunity to express his great indebtedness to Dr. T. K. Huang under whose supervision the present work is carried out. Thanks are also due to Messrs. M. N. Bien, C. C. Biq and P. Chen for much information and for assistance in making collections in the field. Acknowledgment should also be made to Prof. P. L. Yuan and Mr. T. F. Hou for many valuable communications.

*Received for publication in December 1943.

II. DESCRIPTION OF SECTIONS

1. *Wuhuashan Section* (Pl. I, section 1). Wuhuashan[1] is situated about 35km SE of Yümenhsien[2] or 10km W by S of Shangchihchinpu[3]. The succession of Carboniferous rocks in this hill is, in descending order, as follows.

Super-formation: Cretaceous or early Tertiary arkosic sandstone alternating with red shales, sandstones, and conglomerates with "Dreikanter."

Unconformity

Carboniferous:

4 Shales and sandstones, weathering brown .... 21 m

3 Grey to brown shales and sandy shales .... 35 m

2 Coarse grained, sandy, crinoidal-limestone with *Lophophyllum (Lophophyllidium)* sp., *Eupachycrinus* aff. *linchengensis* Tien, *Eup.* sp., *Productus* cf. *taiyuanfuensis* Grabau, *Linoproductus cora* (d'Orbigny), *Choristites* cf. *pavlovi* (Stuckenberg), *Ch. norini* Chao, *Spirifer* aff. *fasciger* (Keyserling), *Martinia* sp. (fK41-7) .... 2-4 m

1 Laminated purple clay .... 28 m

Unconformity

Subformation: Nanshan Series

Dark green submetamorphic sandstones and shales with quartz veins.

2. *Peiyangho Section* (Pl. I, section 2). The area in which Carboniferous strata are exposed is a desolate badland near the village of Peiyangho[4] about 45km SW of Chiayükuan[5]. The section can be summarized as follows.

Super-formation: Taihuangkou Series of grey to black shales with sandstone layers.

Carboniferous:

2 Black shale, brown sandstone with very thin coal seams .... 60 m

1 Black shale, brown sandstone with coal seams and 3 layers of limestone, containing Orthothetinae, *Chonetes* cf. *carbonifera* Keyserling, *Productus* sp., (fK41-8, fK41-7b, fK41-7a). These layers, each less than 1 m in thickness, are separated from one another by sandy shales 14-18 m in thickness .... 60 m

Base covered.

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1. 五華山; 2. 玉門縣; 3. 上赤金堡; 4. 白楊河; 5. 嘉峪關.

3. *Huangtsaoying Section* (Pl. I, section 3). The Carboniferous of Huangtsaoying[1], a small coal mining district about 9km north of Chiayükuan, consists chiefly of shales and sandstones, limestones being entirely wanting.

Super-formation: Taihuangkou Series of shales, sandstones and conglomeratic sandstones, with *Pecopteris* cf. *femineoformis* (Schloth.) Sterzel, *Cordaites* aff. *principalis* (Germ.) H. B. Gein; and *Cord* sp. (fK41-16).

Carboniferous:

3	Sandstone, shale with conglomerate	20 m
2	Workable coal seams and yellowish brown calcareous shale with *Linoproductus cora* (fK41-16a)....	10 m
1	Sandstone interbedding with shale with conglomerate at the base	25 m

Unconformity

Sub-formation: Nanshan Series.

Brownish submetamorphic sandstone with quartz veins.

4. *Liaokaoshan Section* (Pl. I, section 6). Liaokaoshan[2] is 5 km W by S of Shantanhsien[3]. The section is, according to Mr. M. N. Bien, as follows.

Super-formation: Taihuangkou Series; shale with *Annularia* sp. (fK41-70) and quartzitic sandstone intercalating with coal seams.

Carboniferous:

Black calcareous shales and workable coal seams, with *Rhipidomella* sp., *Chonetes pygmaea* Loczy, *Ch. carbonifera* Keyserling, *Productus* cf. *taiyuanfuensis* Grabau and *Marginifera pusilla* Schellwien (fK41-72) .... 58 m

Base not exposed, where the Nanshan Series together with granite, is thrust upon the Carboniferous beds.

5. *Sinho Section* (Pl. I, section 7). The village of Sinho[4] is some 25km SE of Shantanhsien, and is well-known for the numerous coal-fields occurring nearby. The Carboniferous sequence observed in the coal-fields is given, in descending order, as follows:

Super-formation: Taihuangkou Series; sandstones and shales with workable coal seams and plant fossils including *Pecopteris (Asterotheca) orientalis* (Schenk) Potonié, *P. (Ptychocarpus) unites* Brgn., *Sphenophyllum verticillatum* (Schloth.) Brgn., *S.* sp., *Bowmanites* sp. (fK41-52).

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1. 黄草營; 2. 瞭高山; 3. 山丹縣; 4. 新 河.

Carboniferous:

7	Shale with thin coal seam	5 m
6	Shale with thin-bedded sandstone	7.5 m
5	Brownish limestone with *Pseudofusulina vulgaris* (Schellwien), *P.* cf. *complicata* (Schellwien), *P.* cf. *cericalis* (Lee), *P. valida* var. *exigua* (Schellwien), *P.* sp., *Chonetes* sp., *Marginifera* sp., *Juresania juresanensis* (Tschernyschew) (fK41-50b, fK41-51, fK41-57)	1 m
4	Shale with thin workable coal seam	6 m
3	Gray shale with thin-bedded sandstone	12 m
2	Gray compact limestone with small fusulinoids and *Chonetes* cf. *pygmaea* Loczy, *Productus* cf. *taiyuanfuensis* Grabau, *Linoproductus* sp. A, *Linop.* sp. B., *Marginifera pusilla* Schellwien, ? *Uncinulus* sp. (fK41-50a, fK41-51, fK41-54, fK41-55, fK41-57)	2 m
1	Thin-bedded sandstone and shale	10 m

Base covered.

6. *Yanghukou Section* (Pl. I, section 9). Carboniferous fossils occur in abundance near the native coal mines of Yanghukou[1], a S-N running valley descending from the Taihuangshan[2] range toward Tingchiangmiao[3] in Shantanhsien. The locality is some 60km SE of the latter town and 45km from Yungchanghsien[4]. Unfortunately, no outcrops of the fossiliferous horizon were observed, the fossils having been collected in detached fragments or débris by hill slopes. The section is roughly summarized as follows in descending order:

Super-formation: Taihuangkou Series.

Carboniferous:

4	Yellow to brown sandstones alternating with grey and black shales containing thin seams of anthracitic coal	28 m
3	Quartzite (similar to 1)	10 m
2	Thin impure greenish gray fossiliferous limestone (probably 2 layers)..	8 m
1	Whitish quartzite weathering reddish	8 m

Unconformity

Sub-formation: Nanshan Series, submetamorphic greenish sandstone with quartz veins.

1. 羊虎口; 2. 大黄山; 3. 定羌廟; 4. 永昌縣.

The fossils collected from the limestone are dominated by brachiopods, while fusulines, corals and molluscs are also abundant (fK41-45, fK41-45a, fK41-45b, fK41-46). They are: *Fusulina quasicylindrica* (Lee), *Pseudofusulina* sp., *Bothrophyllum* sp. A, *B.* sp. A var., *B.* sp. B, *B.* sp. C, *B.* sp. D, *Bradyphyllum bellicostatum* Grabau, *Rossophyllum* sp. A, *Hapsiphyllum mouhouense* Grabau, *H.* sp. A, *Enteletes lamarcki* Fischer, *Streptorhynchus* sp., *Orthotheles* sp., *Chonetes* cf. *semicircularis* Chao, *Ch. carbonifera* Keyserling, *Productus gratiosus* var. *occidentalis* Schellwien, *Pr. grueneivaldti* Krotow, *Pr.* sp., *Linoproductus tenuistriatus* (De Verneuil), *Echinoconchus elegans* (M'Coy), *Ech. punctatus* (Martin), *Ech.* sp., *Juresania* cf. *juresanensis* (Tschernyschew), *Avonia* sp. A, *A.* sp. B, *Buxtonia* sp., *Marginifera loczyi* Chao, *Uncinulus* aff. *timorensis* Davidson, *Choristites mosquensis* Fischer, *Ch. loczyi* Fredericks, *Ch. yanghukouensis* Chao, *Ch.* sp. A, *Ch.* sp. B, *Brachythyrina strangwaysi* De Verneuil, *Bra. strangwaysi* var. *lata* Chao, *Bra. strangwaysi* var. *longa* Chao, *Squamularia ovata* Chao, *Sq.* sp. A, *Sq.* sp. B, *Hustedia remota* (Eichwald), *Dielasma* aff. *vesicularis* De Koninck, *Athyris* sp. A, *A.* sp. B, *Martinia* sp., *Temnochailus* sp., *Nautilus* sp., *Phillipsia kansuensis* Loczy.

III. CORRELATION OF THE DIFFERENT SECTIONS

The Middle Carboniferous Yanghukou Series. The fauna of the Yanghukou Series at Yanghukou is characterized by *Fusulina cylindrica*, *Enteletes lamarcki*, *Productus gratiosus* var. *occidentalis*, *Marginifera loczyi*, *Choristites mosquensis*, and *Brachythyrina strangwaysi*, species frequently found in the Penchi Series of North China, with which it is to be correlated. The Yanghukou fauna, however, is decidedly richer and more varied than the Penchi fauna. The simple corals led by species of *Bothrophyllum* in the former are not found in the latter, which furnish species of *Chaetetes* and *Lithostrotion*, genera conspicuously absent in our collection. It is thus seen that the Yanghukou fauna is not identical with the Penchi fauna.

Besides Yanghukou, the Yanghukou Series is also found at Lichiachuan, Hungshanyao, Mokou and Yaokou, according to P. L. Yuan [31, 32].

The Upper Carboniferous Taiyuan Series. That the horizons with marine fossils at Wuhuashan, Liaokaoshan and Sinho belong to the Taiyuan Series of North China is shown by the occurrence in them of typical Taiyuan species like *Pseudofusulina vulgaris*, *Productus taiyuanfuensis*, *Chonetes pygmaea*, *Marginifera pusilla*, *Choristites pavlovi*, *Ch. norini*, etc. The close similarity between the Taiyuan Series and the coal-bearing series of western Kansu is not only found in the fauna but also in lithological characters. In Shansi, the Taiyuan Series is directly preceded by the Penchi Series and is apparently conformably followed by the Shansi and Shihhotze Series, whilst the coal-bearing series in western Kansu is underlain by the Yanghukou Series [25] and succeeded by the Taihuangkou Series whose characters are strikingly similar to those of the Shihhotze Series. Evidently, conditions of sedimentation in Shansi were not different from those in western Kansu along the northern foot of the Nanshan Range.

C. C. Sun [25] coined the term "Obo Series" for the coal-bearing rocks occurring between the Yanghukou Series and the Taihuangkou Series. It is shown by the present study that the Obo Series is nothing but the true equivalent of the Taiyuan Series. It appears therefore convenient to apply this well-known name to western Kansu and consequently the creation of a new term becomes superfluous. On the other hand, the Yanghukou Series is conformably succeeded by the Taiyuan Series and being lithologically similar to this latter, it can only be distinguished therefrom by its fauna. Thus a comprehensive name for these two formations seems necessary, at least for future mapping purposes. Dr. T. K. Huang suggests the name Yenchihshan Series[1] for them, which is accepted in the present contribution.

It is to be noted however that the Taiyuan Series is much better and more extensively developed than the Yanghukou Series. In many places where the latter is absent, the Taiyuan Series comes directly upon the Pre-Carboniferous Nanshan Series. This is the case at Wuhuashan, at Huangtsaoying, at Liaokaoshan and at many other places (Pl. I). Evidently, the Taiyuan sea in the Kansu Corridor was transgressive, and the fact that the thickness and lithological characters of the Taiyuan beds are different in different sections points to the suggestion that the shore-line of this sea was fluctuating and lay very close to the already existing "Peishan" mountains to the north of the Corridor.

IV. PALEOGEOGRAPHY

The coal-bearing rocks occurring in the Peishan to the north of the Corridor were found by Yuan [33], Huang [15] and Sun to belong not to the Carboniferous but to the Jurassic. They lie unconformably either upon Pre-Cambrian crystalline rocks or upon the Nanshan Series. Though Obrutchev [21] considers the limestones

1. Yenchihshan 焉支山 is the old name for Taihuangshan, a well-defined mountain range between Shantanhsien and Yungchanghsien.

in his section near Ningyuanpu as Carboniferous, yet they look quite unlike the late Carboniferous Yenchihshan Series and did not furnish us any determinable fossils after careful hunting. It thus seems probable that the Yenchihshan sea did not invade the Peishan region of Kansu. In the Alashan region similar conditions might have prevailed, since Yuan [33] found Mesozoic and Tertiary continental rocks resting directly upon Proterozoic or at least early Paleozoic gneisses and granites. It is only when we go eastward into the Alashan Range, that we are again able to find Middle and Upper Carboniferous marine strata, which however are gradually replaced by contemporaneous continental deposits toward the north so that at "Yinzechan" and "Arbous Oula" Teilhard [28] actually found them. East of Arbous Oula, any possible occurrence of Carboniferous rocks is masked by the Ordos desert and it is not until we reach Paotehhsien[1] in Shansi and Tsingshuiho[2] in Suiyuan that the Penchi and Taiyuan Series are again to be met with. To the north of these latter places continental Carboniferous deposits were again found by Sun [23, 24] upon a floor of Archaean gneisses.

From the foregoing considerations it appears sufficiently clear that the shoreline of the late Carboniferous Yenchihshan sea was roughly marked by the foot of the present Peishan, trending in a WNW-ESE direction. East of Wuwei (Liangchowfu) it swept round toward the NE until near Arbous Oula whence it crossed the Ordos to reach Tsingshuiho in Suiyuan near the 40th parallel. Thus side by side with the Yenchihshan sea there occurred a continuous landmass immediately to its north. This landmass was termed by Huang[3] [14] the Great Wall Axis while its Ordosian part was called Ordosia by Grabaü [7].

Recent field studies reveal the presence of marine Carboniferous deposits immediately east of the Liupanshan, whereas in the region to the west of the latter range and to the south of Lanchou only gneisses and crystalline schists are here and there to be seen under a thick and extensive cover of red beds and eolian loess. These crystalline rocks, being at all events older than the Carboniferous, formed another landmass which bordered the Yenchihshan sea to the north. It is termed by Huang [15] the Lungsi mass.

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1. 保德縣; 2. 清水河.

3. The Great Wall being an artificial structure, I would propose to change the name of this important landmass to "Inner Mongolian Axis."—T. K. Huang.

During the Upper Carboniferous (and also Permian) there existed another important seaway with a different fauna. It lay to the north of the Great Wall Axis and has been termed by Huang [14] the Jisu Honguer sea. According to Yuan [33] continental Carboniferous rocks occur just north of the Muni-Ula, which thus formed the southern limit of the Jisu Honguer transgression.

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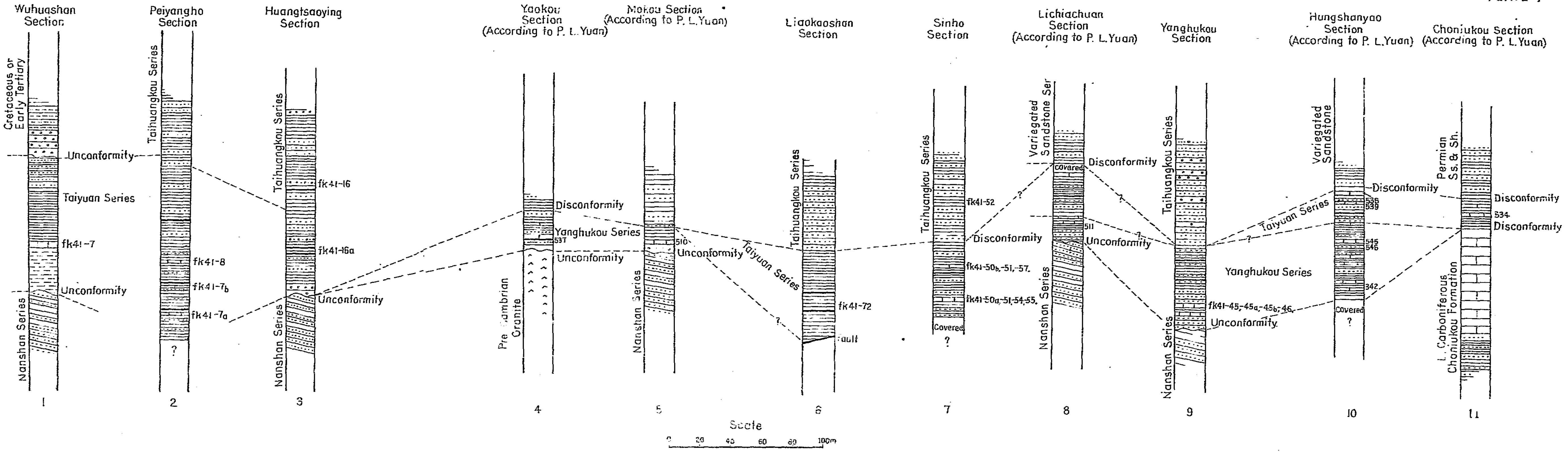
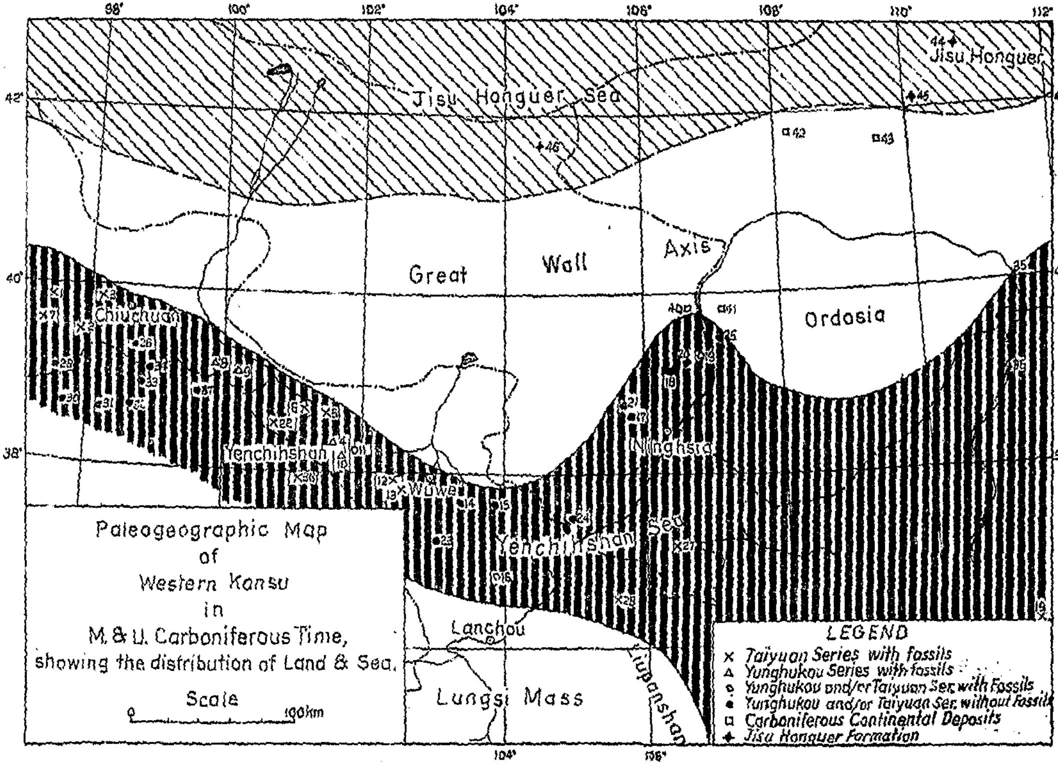
EXPLANATION OF PLATES

Plate I. Columnar sections in western Kansu showing the stratigraphy of Middle and Upper Carboniferous.

Plate II. Palaeogeographic map of western Kansu in Middle and Upper Carboniferous time, showing the distribution of land (blank) and sea (shaded). Numbers are the localities studied:

1. Wuhuashan	五華山	2. Peiyangho	白楊河	3. Huangtsaoying	黃草營
4. Yanghukou	羊虎口	5. Sinho	新 河	6. Liaokaoshan	瞭高山
7. Maopula	毛不拉	8. Yaokou	窰 溝	9. Mokou	墨 溝
10. Lichiachuan	李家泉	11. Hungshanyao	紅山窰	12. Panchiatapan	潘家大板
13. Chouniukou	臭牛溝	14. Tachin	大 靖	15. Hungshuipao	紅水堡
16. Talapai	大拉牌	17. Taerhlintzukou	塔爾嶺子溝	18. Wangchuankou	王全溝
19. Shihtsueizu	石嘴子	20. Chenikuan	正義關	21. Fanchiaying	樊家營
22. Nanshihying	南石營	23. Wutsaolin	烏稍嶺	24. Iwanchuan	一碗泉
25. According to C. C. Sun's map without locality name.		26. Kingfussu	金佛寺	27. Yuwanghsien	豫旺縣
28. Haiyuanhsien	海原縣	29-34. According to Obrutchev without locality names.		35. Chingshuiho	清水河
36. Paotehsien	保德縣	37. same as 25		38. Obohsien	俄博縣
39. Linfenhsien	臨汾縣	40. Yinzechan		41. Arbous Oula	
42-43. According to P. L. Yuan without locality names.		44. Jisu Honguer	哲 斯	45. Pelingmiao	百靈廟
46. Abder Tu					


Wuhuashan Section
Peiyangho Section
Huangtsaoying Section
Yaokou Section (According to P. L. Yuan)
Mokou Section (According to P. L. Yuan)
Liaokaoshan Section
Sinho Section
Lichiachuan Section (According to P. L. Yuan)
Yanghukou Section
Hungshanyao Section (According to P. L. Yuan)
Choniukou Section (According to P. L. Yuan)
Cretaceous or Early Tertiary
Unconformity
Taiyuan Series
fk41-7
Nanshan Series
Taihuangkou Series
fk41-8
fk41-7b
fk41-7a
fk41-16
fk41-16a
Disconformity
Yanghukou Series
Pre-Cambrian Granite
Fault
fk41-72
fk41-52
fk41-50b,-51,-57.
fk41-50a,-51,-54,-55.
Covered
Variegated Sandstone Ser
fk41-45,-45a,-45b,-46.
Variegated Sandstone
Permian Ss. & Sh.
L. Carboniferous Choniukou Formation
1
2
3
4
5
6
7
8
9
10
11
Scale
100m


Jisu Honguer Sea
Jisu Honguer
Great Wall Axis
Ordosia
Chiuchuan
Yenchihshan
Wuwei
Ninghsia
Yenchihshan Sea
Lanchou
Lungsi Mass
Liupanshan
Paleogeographic Map
of
Western Kansu
in
M. & U. Carboniferous Time,
showing the distribution of Land & Sea.
Scale
0 100km
LEGEND
× Taiyuan Series with fossils
△ Yunghukou Series with fossils
○ Yunghukou and/or Taiyuan Ser. with Fossils
● Yunghukou and/or Taiyuan Ser. without Fossils
□ Carboniferous Continental Deposits
✦ Jisu Honguer Formation

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A Detailed Section of the *Gigantopteris* Coal-bearing Formation near Shuicheng, Western Kueichow*

By

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With 1 Text-figure.

The *Gigantopteris* coal-bearing formation is widely distributed in western Kueichow. In the Tahopien[1] coal-field of Shuicheng [2], this formation has been observed by different investigators like S. S. Yoh, C. J. Peng and T. P. Chai. An almost complete section of it, from the top of the Omeishan basalt to the base of the Lower Triassic, is measured by the writer near Feichiachai [3], a small village situated about 25 km to the northwest of the city of Shuicheng (Fig. 1). Since *Gigantopteris* is generally known to be confined to certain horizons, the discovery of *Gigantopteris nicotianaefolia* Schenk throughout the whole formation is of some importance and it

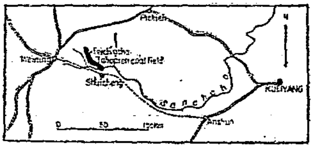

Fig. 1. Map showing the location of the Tahopien coal-field, Shuicheng.

*Received for publication in April 1943.

1. 大河邊; 2. 水城; 3. 費家寨.

seems desirable to give a brief account. The succession of the formation in question is, in descending order, as follows[1]:

Super-formation: Lower Triassic beds with *Oxytoma* and *Pseudomonotis*

——————Disconformity——————

Gigantopteris coal-bearing formation

58.	Reddish yellow fine sandy shale	0.1 m
57.	Coal seam	2.0 m
56.	Yellow sandstone and shale with iron concretions	4.0 m
55.	Coal seam	1.2 m
54.	Thick-bedded green sandstone alternating with pale yellow shale with *Gigantopteris nicotianaefolia* Schenk, *Rhipidopsis lobata* Halle, *Pecopteris* sp. *Taeniopteris* sp. (IIIi 176)	17.0 m
53.	Coal seam	0.1 m
52.	Green sandstone alternating with pale yellow shale	8.0 m
51.	Grey shale with *Gigantopteris nicotianaefolia* Schenk (IIIi 166)	3.5 m
50.	Green sandstone	5.0 m
49.	Coal seam	1.0 m
48.	Grey sandstone and shale with fragments of fossil plants	19.0 m
47.	Greenish grey shale with *Chonetes* cf. *substrophomenoides* Huang, *Streptorhynchus* cf. *kayseri* Schellwien, *Uncinulus timorensis* (Beyrich), *Productus* sp., *Martinia* (?) sp., *Spirifer* sp., *Acanthopecten* sp., *Phillipsia* sp. (IIIi 160 and 167)	4.0 m
46.	Yellow sandstone and grey sandy shale	40.0 m
45.	Coal seam	0.5 m
44.	Grey sandstone with cross-bedding	11.0 m
43.	Coal seam	1.0 m
42.	Grey shale	5.0 m
41.	Coal seam	0.4 m
40.	Grey and yellow shale	3.0 m
39.	Coal seam	0.7 m
38.	Grey clay shale	3.0 m
37.	Coal seam	0.5 m

1. All the fossils listed below are preliminarily identified by the writer himself.

36. Grey clay shale .... 3.0 m
35. Yellow sandstone with cross-bedding .... 2.0 m
34. Grey shale and whitish grey clay shale .... 2.0 m
33. Grey sandy shale alternating with yellow shale .... 17.0 m
32. Coal seam .... 0.1 m
31. Whitish grey clay shale .... 0.5 m
30. Grey sandy shale with fossil wood and with *Gigantopteris nicotianaefolia* Schenk, *Protoblechnum wongii* Halle, *Rhipidopsis lobata* Halle, *Lobatannularia ensifolius* Hall, *L. heianensis* (Kodaira) Halle, *Asterophyllites pingloensis* Sze, *Sphenophyllum verticillatum* (Schloth.) Brgn., *Pecopteris hirta* Halle, *P. lativenosa* Halle, *Sphenopteris* sp., *Taeniopteris* sp. (Illi 165) .... 5.0 m
29. Yellow and grey shale .... 11.0 m
28. Coal seam .... 0.3 m
27. Whitish grey clay shale .... 0.7 m
26. Grey sandy shale with fragments of fossil plants .... 8.0 m
25. Coal seam .... 0.1 m
24. Light grey shale with iron concretions .... 1.2 m
23. Grey sandy shale with abundant plant-fossils: *Gigantopteris nicotianaefolia* Schenk, *Rhipidopsis baieroides* Kawasaki et Konno, *Lobatannularia* cf. *heianensis* (Kodaira) Halle, *L. lingulatus* Halle, *Sphenophyllum verticillatum* (Schloth.) Brgn., *S.* sp., *Pecopteris* sp. (Illi 175) .... 3.5 m
22. Yellow sandstone alternating with grey shale .... 5.0 m
21. Brownish grey shale with *Pecopteris arcuata* Halle, and *P.* sp. (Illi 172) .. 2.0 m
20. Yellow and grey shale .... 3.0 m
19. Yellow sandstone with *Gigantopteris nicotianaefolia* Schenk (Illi 171) ...... 1.0 m
18. Grey and yellow shale .... 18.0 m
17. Yellow coarse sandstone with abundant plant-fossils: *Pecopteris anderssonii* Halle, *P.* (*Asterotheca*) *norinii* Halle, and *Sphenophyllum* sp. (Illi 170) .. 2.0 m
16. Brown and yellow clay shale .... 7.0 m
15. Yellow, grey and reddish grey shale .... 15.0 m
14. Coal seam .... 0.2 m
13. Grey and yellow shale with *Gigantopteris nicotianaefolia* Schenk, *Rhipidopsis baieroides* Kawasaki et Konno, *Sphenophyllum verticillatum* (Schloth.) Brgn., *S. sino-coreanum* Yabe, *S.* sp., *Plagiozamites oblongifolius* Halle, *Lobatannularia* sp., *Pecopteris* sp., *Taeniopteris* sp. (Illi 175) .... 25.0 m
12. Greenish grey thick-bedded sandstone with pale yellow sandy shale containing fossil wood .... 15.0 m

11.	White paper shale	1.0 m
10.	Light yellow sandy shale	14.0 m
9.	White paper shale	1.5 m
8.	Yellowish grey sandy shale	7.0 m
7.	Coal seam	0.3 m
6.	Grey sandstone with fragments of fossil plants	8.0 m
5.	Yellowish grey shale with *Gigantopteris nicotianaefolia* Schenk, *Protoblechnum wongii* Halle, *Pecopteris* sp. (Illi 174)	3.0 m
4.	Coal seam	0.3 m
3.	Light grey clay shale	2.3 m
2.	Yellow and dull grey shale with poorly preserved plant fossils including *Gigantopteris nicotianaefolia* Schenk, *Taeniopteris* sp. (Illi 196)	5.0 m
1.	Yellow, brown and grey sandstone	7.0 m

——————Disconformity——————

Sub-formation: Purple tuffaceous shale of Omeishan basalt.

The total thickness of the coal-bearing formation is 327.0 m.

In spite of the presence of *Pecopteris hirta* Halle originally found in the Lower Shihhotze series, most of the fossil plants were described by different authors from the Upper Shihhotze series or from its equivalents in China. It is noteworthy that *Gigantopteris nicotianaefolia* Schenk occurs in eight horizins of the Feichiachai section through a vertical range of 312.7 m. *Asterophyllites pingloensis* was described by Sze[1] from the upper plant bed of the Hoshan formation of Kuangsi and its presence in the Feichiachai section is of some interest. In China, the genus *Rhipidopsis* was only known from Honan[2] and Shansi[3] and its occurrence in beds 13 and 23 of the present section is another striking feature. The remaining fourteen species were all described from Central Shansi[3].

It was formerly believed that the *Gigantopteris* flora is confined to the lower part of the Lopingian[4] or the "Luipakou Coal Series." In view of the present

1. H. C. Sze: On the occurrence of *Gigantopteris* flora in Kuangsi. Bull. Geol. Soc. China, vol. 20, no. 1, p. 38-40, 1940.

2. C. H. P'an: Notes on Kawasaki and Konno's *Rhipidopsis brevicaulis* and *Rh. baieroides* of Korea with description of similar forms from Yuhsien, Honan. *Ibid.*, vol. 16, p. 261-268, 1936-37.

3. T. G. Halle: Palaeozoic plants from Central Shansi. Pal. Sinica, ser. B, vol. 2, fasc. 1, p. 192, p. 252-255, 1927.

4. T. K. Huang: The Permian formations of southern China. Mem. Geol. Surv. China, ser. A, no. 10, p. 62, 1932.

discovery it appears probable that this flora survived even in latest Lopingian time at least in some part of SW China, where the Lopingian is predominantly non-marine.

Finally, the writer wishes to take this opportunity to express his gratitude to Prof. C. Y. Hsieh, Chief of the Mineral Prospecting Bureau, National Resources Commission, for giving him all facilities in carrying out the work in the field. The writer is also much indebted to Drs. T. K. Huang and T. H. Yin for valuable suggestion and careful reading of the manuscript.

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On Tectonic History in Regions East of the Tibetan Plateau from Kansu to Yunnan*

By

L. T. YEH

(Geological Survey of China)

With 2 Plates

During the recent five years I have joined several field parties in the carrying out of geological reconnaissances in regions between the valley of the Huangho and of the Yangtze and in the Sino-Tibetan borderland. This vast territory can be divided into six major geological units, easily recognizable both in structure and relief. They are:

1) The Central Kansu Basin, which lies between the Nanshan and the Tsinlingshan,
2) The Tsinlingshan which divides the drainages of the Huangho and the Yangtze,
3) The Lungmenshan[1], the northern border range of the Szechuan Basin,
4) The Motienling[2], which is intercalated between the Tsinlingshan and the Lungmenshan, and is usually not well differentiated,
5) The Szechuan Basin,
6) The plateau of northeastern Yunnan.

Last year, when I completed my manuscripts of a report on the structure of the Tsinlingshan, it was felt that the origin and cause of the structures still remain

*Received for publication in April 1943.

1. 龍門山; 2. 摩天嶺.

to be deciphered. This has compelled me to make a thorough review of all related literature that was accessible to me, and consequently I gathered and coordinated all the related data and tried different hypotheses to explain the larger geotectonic features. The result is the establishment of some interesting conclusions, which are now treated here, in a much concise form, in the following paragraphs. Before the text is going on, I gladly take this occasion to express my cordial thanks to Dr. T. K. Huang for his frank criticism.

THE CALEDONIAN MOVEMENT

As seen from the correlation table and the idealized section attached herewith, marine Silurian rocks of no less than 1,000m in thickness, are widely distributed in the regions described. The northward transgressive sea ended in the southern part of the Central Kansu Basin, which was probably an oldland at that time, to which we have termed the Kaolan Mass. With the close of the Silurian time the seaways changed considerably; the Devono-Carboniferous rocks, no less than 10,000m in thickness, were then restricted to two eastwest troughs or geosynclines, to be called the *Tsinling geosyncline*, and the *Lungmenshan geosyncline;* and the region of the Plateau of Northern Yunnan. Between these geosynclines there lay the *Motienling geanticline* and the *Szechuan Old Mass,* which were, then, regions emerged and subjected to erosion. The paleogeographic configuration remained essentially the same from the close of the Caledonian movement till the end of Carboniferous. With the opening of the Permian period, all the old landmasses from Kansu to Yunnan subsided, with the result that massive marine limestones were extensively deposited, even more extensive than the Silurian rocks.

The contact between the Silurian and younger rocks is usually represented by a disconformity, with the exception of the Tsinling region where an angular unconformity was observed by Chao and Huang and myself. As stated above, the main issue of the Caledonian movement is the formation of two geanticlines and three geosynclines, which are obviously the outcome of epeirogenic movement, if we accept H. Stille's views. Probably it was the result of large scale crustal tensions, or of tangential stresses acted at great depth. Or, it may be regarded as due to radial adjustment of unbalanced heat energy.

The present state of the earth crust in the described region was probably still quite unstable, and its undationed relief forms roughly an irregular sine curve, which is just the reverse of the ancient Caledonian relief.

PRINCIPAL DIRECTION OF THE CRUSTAL STRESS

Whenever the very complicated problem of stress is touched upon, we had better recall the well-known experiment of B. Willis on folding of strata, which postulates that the strata nearer to the applied force are folded earlier. With the opening of the Triassic period the adjustment of the unbalanced crustal blocks was initiated and culminated first in the Tsinling geosyncline, with the result that that part of the earth crust was strongly compressed, regionally metamorphosed, and finally completely emerged. Hence, there were no marine or even continental Triassic rocks ever deposited in that territory. Toward the south in the Lungmenshan geosyncline, the withdrawal of the sea did not take place until at the end of the Triassic time before the Anyuanian movement came into play. Further south the existence of the Anyuanian movement became much obscured and can only be detected by very detailed mapping work.

Although radial adjustment was then active in the mountainous regions of the Tsinling, orogenic movements were hardly recorded during the time interval from the Jurassic to the Cretaceous. Toward the close of the Cretaceous, an orogenic movement again took place in the Tsinling and north of it, as is revealed by the unconformable relation between the Mesozoics and its overlying Tertiary Kansu Series, which was in turn affected also by folds and posthumous faults along basin margins. In regions south of the Tsinling, in the Szechuan Basin, the Cretaceous red beds were also considerably folded, but here we can not define the exact age of the movement because of the absence of younger deposits. In northern Yunnan where stratigraphic unconformities appear to be absent prior to the deposition of the red beds, the age of the principal orogenic movement is to be ascribed to post-Cretaceous.

As summarized above, the withdrawal of the transgressive sea and the folding of the earth crust all began in the north and were gradually transmitted southward. Hence by applying Willis' experiment we come to the conclusion that the principal direction of the crustal stress must have been from north to south.

Although no distinct orogenic zoning can be made in the regions described, yet by stressing more upon the importance of the order of appearance of the diastrophic (orogenic or epeirogenic) paroxysms recorded in their respective structural histories we may regard the Central Kansu Basin, the Motienling Geanticline and the Szechuan Basin as the Caledonides, the Tsinlingshan and Nanshan as the Variscides, the Lungmenshan as the Anyuanides, and the northern Yunnan Plateau as the Alpides.

The Liupanshan of the Central Kansu Basin, though Alpides in its broad sense, is regarded as the Lunshanides, because it is derived from the Lunshan Movement of post-Pliocene age.

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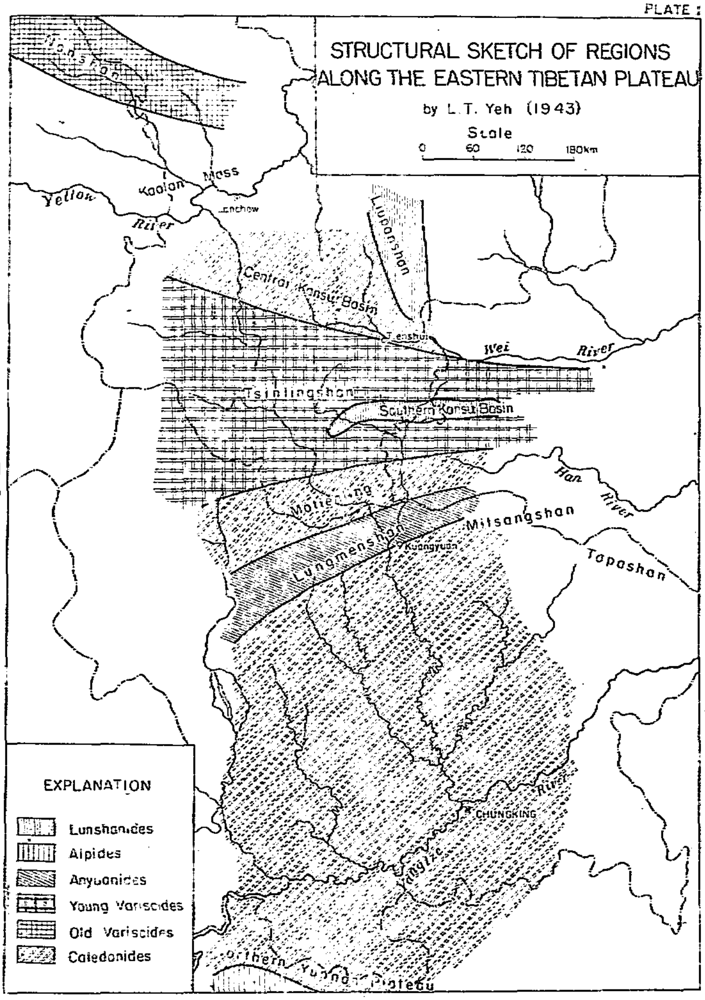
EXPLANATION OF PLATES

Plate. I. Structural sketch of regions along the eastern Tibetan Plateau.

Plate II. Correlation table and structural sections.

PLATE :


STRUCTURAL SKETCH OF REGIONS
ALONG THE EASTERN TIBETAN PLATEAU
by L. T. Yeh (1943)
Scale
0 60 120 180km
Yellow River
Koolan Mass
Wei River
Tsinlingshan
Southern Kansu Basin
Central Kansu Basin
Luponshan
Han River
Mitsangshan
Lungmenshan
Kuangyuan
Tapashan
CHUNGKING
Yangtze
River
EXPLANATION
Lunshanides
Alpides
Anyuanides
Young Variscides
Old Variscides
Caledonides

Periods \ Regions	Central Kansu Basin	Tsinlingshan	Motienling	Lungmenshan	Szechuan Basin	Northern Yunnan Plateau
Tertiary	•••••••••	•••••••••••	X	X	?	•••••••••••••
Cretaceous	•••••••••	•••••••••••	?	•••	••••••••••••••••••••••	•••••••••••••
Jurassic	•••••••••	•••••••••••	?	•••	••••••••••••••••••••••	•••••••••••••
Triassic	X	X	X	———	———	———
Lopingian	X	———	X	———	———	———
Yangsinian	X	———	?	———	———	———
Carbonic	X	———	?	———	X	———
Fengninian	X	———	X	———	X	———
Devonian	X	———	X	———	X	———
Silurian	?	———	———	———	———	———
Pre-Silurian	———	?	———	———	———	———

X Wanting, ——— Marine deposits, ••• Continental deposits,
? Possibly present (Continental or marine)

Fig. 1. Stratigraphical Correlation Table for the Sino-Tibetan Border

Fig. 2. Geomorphological profile through the same regions
(vertical scale highly exaggerated)

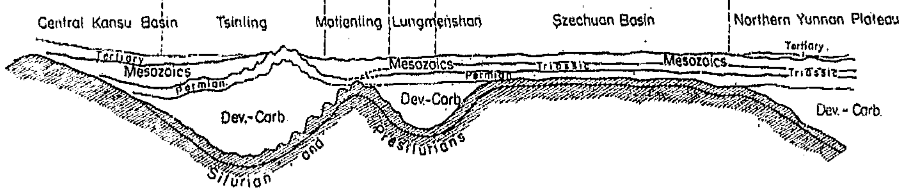


Fig. 3 Idealized structural section through the same

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On Minor Structures*

By

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With 3 Plates.

PREFACE

From field experience and data accumulated in recent years several short papers on field geology have been written. The present paper embodies only part of the subject-matter, and is meant for open discussion. It will be noticed that every subheading is treated on its own account, and is independent of one another.

INDIRECT METHODS OF DETERMINING THE STRIKE OF BEDDING PLANE

Sedimentary rocks commonly exhibit more or less conspicuously layered structure. It is sometimes easily recognized in the field from different colors, different textures, or from different composition of consecutive beds. But sometimes, usually in massive limestones, the bedding plane is not easily recognizable. In such cases the strike of the bedding plane must be determined indirectly.

1. Where the joints are well developed, they are easily mistaken for bedding planes. On careful examination, we can, however, recognize the joints. Although they are arranged in parallellism, they can not, as a rule, be traced along the same plane for any great distance; but are more or less displaced as they extend. With the bedding plane, this is not the case. It can be traced in a section either from the top to the bottom, or from the right to the left, according as the bedding plane stands vertically or is inclined. (Pl. I, fig. 1).

2. Field experience shows that mud-cracks which occur near by the foot of a hill are sometimes arranged in a certain direction in continuity and parallelism

*Received for publication in May 1943.

for a considerable distance, while shorter and displaced ones run across them as shown in Pl. I fig. 2. In such cases the longer cracks often assume the same direction as that of the bedding planes.

3. In the limestone-field, small, round depressions are frequently marked by parallel lines or steps with a suture-like arrangement (Pl. I, fig. 3). They always indicate the bedding planes.

4. It is well known that streams often flow along a fracture; but sometimes they also follow the contact of lithologically different formations, that is, roughly along the strike of a bedding plane (Pl. I, fig. 4).

5. Roof and/or floor of a natural cave in most cases roughly coincide with the bedding planes.

TRUE AND APPARENT UNCONFORMITIES

About a century ago, Elie de Beaumont used, probably for the first time, the unconformable relation between different formations for determining phases of mountain-making. This is still considered as the most important method. Unconformity as is generally accepted, is a facies symptom which represents a folded and uplifted series of beds sunk after its denudation for a shorter or longer interval, and then superposed by another younger series of sediments. An erosional surface and an intraformational conglomerate, especially an angular contact, are often found between the folded underlying and the horizontal, or gently dipping overlying strata, if the later sediments were tilted by a subsequent movement. The first two characteristic features in an unconformable contact of two different geological formations are sometimes obscure or even absent; whereas the third—angular contact—often remains visible. For, in fact, conspicuous masses of conglomerate spreads only, as a rule, over some limited area of sharp inclination above the general plane of deposition, while in extensive flat surfaces of deposition they may be restricted, thin, inconspicuous or even entirely absent. The erosional surface may not be clearly visible when the erosional interval was not long enough to allow the removal of an appreciable thickness of beds. In case of absence of intraformational conglomerate and erosional surface, unconformity must be detected from other tectonic features.

Similar to unconformity, and sometimes mistaken for it by a beginner of field geology, are two other features: One of them is disharmonic folding and the other thrust, When a thick series of strata composed of both competent and incompetent beds, is subjected to the same magnitude of compression at the same time, the incompetent beds are in general more strongly folded than the competent ones; the two kinds of beds present, therefore, an arrangement of angular contact with each other. This phenomenon is called disharmonic folding. From fossil contents in the successive formations or from comparative stratigraphical studies, we can definitely ascertain than both the incompetent and competent beds, though not uniformly folded, are in fact of continuous nature as regards their deposition.

When a group of strata is folded under a great magnitude of compressive stress or through a relatively mild stress operated for a long time, thrusts are, as a rule, the result. In a thrust zone the overthrusting beds often angularly rest upon the underthrusting ones, no matter the overlying part is of the older or younger age, or both of them are of the same formation.

From the above statements it is clear that angular contact may occur in different modes. Every type has its own geological significance. The first of the three modes mentioned above indicates that a long interrupted interval in deposition was required in uplifting and down-sinking between the underlying and overlying formations; the second is merely an unequal folding in response to the different physical characters of rocks; and the third exhibits only a broken phase of a continuous folding. These phenomena liable to cause confusion in the field deserve therefore a comparative treatment from the point of view of observation, and at the same time, they must be definitely separated from one another in order to connote their different origin. For this purpose the first mode of occurrence of angular contact with a depositional break may be designated as true- or T-unconformity, and the last two as apparent or A-unconformities.

DETERMINATION OF UNCONFORMITY IN CASE OF ABSENCE OF BASAL CONGLOMERATE AND EROSIONAL SURFACE

That a group of horizontal or gently dipping strata rests upon the eroded edges of an older, folded series is designated as an unconformity*. The discordant relation between the two series often varies from place to place. They may cross

*What the writer here discusses is only confined to the sedimentary rocks. The relations between sedimentary series and igneous masses are not taken into consideration in this paper.

each other in one locality at steep angles, or may follow each other with a slight difference of dip in another locality. In the extreme case the two series may even appear to be conformable. Such a state of affair follows from the consideration that the intensity of folding, especially in an extensive area, is not everywhere uniform or equal, but often decreases in a certain direction along which the beds behave differently in different localities in response to a given stress system.

In a thick series of sediments it often happens that certain beds (competent) can transfer stresses and lift the weight of overlying rocks better than others (incompetent). Where such a thick series of strata is subject to compression the incompetent beds often experience much stronger folding than the competent ones, and thus an angular contact will be produced between them.

The angular contact in the first case is a true- or T-unconformity and that in the second case an apparent- or A-unconformity. It is of great importance for geologists to distinguish these two types, for each has its own geological significance, and each represents certain different condition under which it was produced.

As stated above T-unconformity is brought about by the redeposition of a younger series on the eroded edges of an older, folded series. Consequently there will be an erosional surface between the two series. The erosional surface may be recognized either by the

a. basal conglomerate of the younger formation, or by the

b. incomplete folds of the older formation.

Where the erosional surface is not clearly visible the true unconformable relation between the over- and the underlying formations can still be positively recognized by a similar arrangement of folds of both layers, incompetent, as shales, and competent, as sandstones and limestones, which may happen to occur in the older formation.

If an incompetent series has two competent beds above and below we can recognise the A-unconformity by the same intensity in folding of the two competent beds, even if the incompetent beds are discordant to them. When the lower competent rock is absent or invisible we can, however, determine that the unconformity is an apparent one by the completeness of folds of the incompetent layers.

A good example is found at Lungwangmiao in the western hills of Kunming, where the Lower Cambrian is composed of shales with *Redlichia* alternated with argillaceous and siliceous, thick-bedded limestones. All these are folded in anticlines and synclines that affect both the competent and incompetent beds alike. The massive Carboniferous limestones rest directly upon the Cambrian beds with an angular contact. There is neither a basal conglomerate nor an erosional surface to be seen between the two formations. Within a short distance to the south from Lungwangmiao the Cambrian beds seem to be conformable with the Carboniferous. Basing on the statements of the foregoing paragraphs we recognize definitely that the Lower Cambrian is truly unconformably overlain by the Carboniferous.

EXPLANATION OF THE ARRANGEMENT OF FRACTURE CLEAVAGE IN FOLDING

Fracture cleavage has been studied by many eminent investigators. The results of their investigations have been published in several papers. In spite of the divergent opinions concerning the relations of (a) fracture cleavage to crystallization, (b) fracture cleavage to pressure and movement and (c) crystallization to pressure and movement, one fact is maintained and accepted by all of them, that is, the fracture cleavage bears in most cases a close relation to the folding when both features are developed contemporaneously. Cleavages are usually parallel, except under special local conditions, to the axial plane of the associated folds, though the strike and dip of the bedding plane may be continuously variable in different parts of folding (Pl. I, fig. 5).

According to the strain ellipsoid principle two systems of fracture cleavage should develop along the two maximum shear planes. Field experience demonstrates, however, that this is rarely the case. In most cases, especially in the strong-folded regions, only one system of fracture cleavage occurs, that runs parallel to the axial plane (Pl. I, figs. 6 & 7). It is caused by the shearing stress along the A-shear plane. The other along the B-shear plane is often obscure.

This phenomenon, simple as it is, is often unexplained. In fact the shearing stress along the B-shear plane still exists, although the cleavage is not developed. The explanation here offered is that the shearing stress along the B-shear plane is spent in the slipping of strata against and over each other. Due to this action the beds are often thickened in the axial parts of anticlines and synclines and the slickensides which are often used as criteria for detecting the direction of movement will appear on the bedding planes under favorable conditions.

DETERMINATION OF FOLD-LIMBS BY MINOR FEATURES

Anticlines and synclines generally occur in a series, one beside another alternatively. Many of them still remain complete, and can be clearly recognized at a sight. But, in most cases they are incomplete, being partially removed by different natural agencies of destruction since they came into existence. In these circumstances special attention should be paid to the minor features, which are preserved in beds, in order to interpret correctly the form of folds. Such features are either primary or secondary.

In entering upon detailed consideration of the problem the fundamental fact should be always kept in view: An anticline always embodies the older rocks in its inner part; while a syncline, on the other hand, embraces the younger rocks in its central part. For this reason one must first of all determine the relative position or age of a series of beds either by the fossil contents in them or by the minor features, as ripple-marks, mud-cracks, rain-drops, foot-prints and current-beddings. All these feature indicate the upper side of the beds [1]. When we find out some of them in each bed we can then correctly reconstruct the fold. An example will be given as follows:

Figure 1 of Plate II represents two limbs of a closed fold. It may be reconstructed in two ways; either as an anticline or as a syncline. If one of the above-mentioned features be found on the outside of the strata, then it would be an anticline. On the contrary, if any one of the features appears in the inner side of the beds these series will be a syncline.

All these features are of primary nature. There are, furthermore, secondary or tectonic ones which have been produced through folding. They are fracture cleavages, drag folds, slickensides or polished surfaces and quartz- or calcite-veins, which cross the bedding and are displaced by the folding. These can also afford some definite hint to a reconstruction of a fold, and will be considered separately.

Fracture cleavages. It is well-known that fracture cleavages are usually parallel, except under special local conditions, to the axial plane of the fold. On this assumption we may infer, with reference to Pl. II, Fig. 2, that the dip-angle of the

1. It is to be noted that the molds or casts of these minor features, when found, will indicate the lower instead of the upper side of beds. Current-bedding, moreover, is to be found neither on the upper nor on the lower side.—*The Editor*.

fracture cleavages is always steeper than that of the right limb, and gentler than that of the left limb, if the fold is an asymmetrical or overturned anticline toward the left hand.

Drag folds. These may indicate the top and bottom of a bed on the limb of a major fold. From field observations we know that the upper beds generally move over the underlying beds toward the anticlinal axis. Thus, Pl. II, Fig. 3 represents the left limb, and Fig. 4 the right limb, of an overturned anticline.

Slickensides. Slickensides or polished surfaces, which appear on the bedding planes of folded strata, are often interrupted by "steps" or rough areas. This feature offers important evidence to show the relative direction of movements of the overlying and underlying beds. In the direction of motion the polished surface usually feel and look much smoother. Two examples are given below. The slickensides represented in Pl. II, figure 5 are exposed on the left hand side and those represented in fig. 6 on the right hand. Let it be known that the smooth direction of the slickensides in the first case shows a downward motion and that in the second case an upward motion. It is evident that Pl. II, Fig. 5 represents the right limb of an overturned anticline and Fig. 6 the left limb of an overturned syncline.

Cross veins. Strata are sometimes cut across by cracks and fissures and then filled by veins. When the strata are folded the veins are often step by step displaced, as shown in Pl. II, Fig. 7. By the relative displacement of the veins we can determine the position of the limb, to which the beds belong, for the veins in the higher beds slide with no exception toward the anticlinal axis.

DETERMINATION OF THE DIRECTION AND THE PITCH OF FOLD-AXES BY THE FRACTURE CLEAVAGE AND SLICKENSIDES

Folds appear in most cases in groups. Their axes sometimes lie horizontally, but, as a rule, more or less inclined. The inclination of the axial line measured from the horizontal is called the pitch. In a complete fold the axis rises on one end, stretches for a certain horizontal distance and sinks down again on the other end. When the folds are complete we can directly measure the direction and pitch of their axes. If the folds are incomplete, as is usually the case, we may determine the axial attitude by means of the relations of the bedding plane to the fracture cleavage and slickensides, either one or both of which may occur in association with the process of folding.

From field observations we understand that the fracture cleavage, especially in an extensive area of regional deformation, is generally parallel to the axial plane of associated folds originated simultaneously with the former. It is evident that the intersection of the axial plane with the bedding plane shows the direction as well as the inclination of the axis if the fold is a pitched one. Similarly, the intersection of the fracture cleavage with the bedding plane can also show the position of the axis in space. Basing on this relation we can find out the direction and the pitch of the axis of folding by the method of stereographic projection as follows (Pl. III, Fig. 1).

Let the strikes of bedding plane and fracture cleavage be N44°E and N68°E respectively. The former dips at 30° and the latter at 54°, both to southeast. By the method of stereographic projection draw a line AB through the centre O, representing the strike of the bedding plane given above. P_1 is a point in the normal to the bedding plane on the sphere, and $\widehat{OP_1}$ representing the dip angle equal to 30°. The great circle AHB is the trace of the bedding plane on the sphere. Similarly, draw a line COD, the strike, and $\widehat{OP_2}$, the dip angle, of the fracture cleavage. CHD is the great circle intersected by the plane of the fracture cleavage with the spherical surface. The two great circles AHB and CHD intersect each other at two points O and H, H is a point on the sphere. Now, the line FOG is the direction (N86°E), and $\widehat{FH}$ the dip angle (20° to east), of the axis required.

Slickensides occur not only in a fault zone, but also on bedding planes along which shearing movement often occurs during the folding. They are always in the direction of movement. From field evidence we know that slickensides due to folding have the same angles and direction as the dip of the bedding plane when the axis of a fold is horizontal, and that they show different angles (always smaller) from the dip angle where the folding axis is somewhat pitched. Based upon these relations the direction and the pitch of the axes of foldings may be determined by the method of stereographic projection (Pl. III, Fig. 2).

Assume that AOB (N60°W) represents the strike, $\widehat{OP}$ the dip angle (40° to southwest), of the bedding plane. The great circle AHB is the trace of the bedding plane on the sphere. The slickensides measured on the same bedding plane is at 32° with the horizontal surface and dips to the left hand of the dip direction. The intersecting point of the slickenside on the sphere must lie on the great circle AHB because the slickenside is on the bedding plane, and furthermore at the point S since

$\overset{\frown}{OS}$ equals to 58°, the complementary angle of the slickenside. Thus, LOM is the projective direction of the slickenside on a horizontal plane. Now, the direction of the dip OP and that of the slickenside OS are not in a straight line, namely, not in the same direction. The axis is, therefore, not in a horizontal position. If the axis is rotated to a horizontal situation, the points P and S should lie in a straight line, Thus we rotate the tracing paper over the Wulff's *Netz* until the points P and S lie on a great circle CKD. In order to carry the axis to the horizontal position we must rotate it over the arc $\overset{\frown}{OK}$, and then P moves along PP_1 to P_1 and S along SS_1 to S_1 contemporaneously. P_1 and S_1 lie, now, in a straight line COD which is the direction of the dip and also of the slickenside. The line FOG drawn perpendicular to COD is the direction of the axis, being horizontal. Let P_1 and S_1 return to their original positions P and S respectively, then F will move to H because of $\overset{\frown}{FH}$ equal to $\overset{\frown}{OK}$, both of which are complementary angles of $\overset{\frown}{OH}$. Consequently, $\overset{\frown}{FH}$ or $\overset{\frown}{OK}$ is the pitch (22° to southeast), and FOG the direction (S32°E), of the axis required.

The determination made by the methods, as mentioned above, is correct only at the locality where the measurements were taken, since the pitching axes do not always continue downwards into the earth with the same inclination, but often undulate, or bend upwards and again downwards at different localities. Again, they do not always extend in a straight direction, but are sometimes virgated or "zopfartig."

It is necessary to add that the methods of stereographic projection, as I have stated above, is applicable only where the fracture cleavage, or the slickensides, occur contemporaneously with the folding.

The direction and pitch of the axes determined by the methods of stereographic projection are sometimes as accurate as those measured directly in a complete fold. But sometimes a slight difference may also occur. This error is generally caused by the following facts: 1. The bedding plane is by no means a perfect plane. 2. The fracture cleavage is in most cases more or less shifted from its original position through the process of weathering and crumbling, so that even though we take readings in the field with much attention the error may still occur. This is more usually the case with the fracture cleavage.

POSTSCRIPT

While in general slickensides occur at angles different from the dip when the fold is somewhat pitched, there is still another case in which slickensides are developed nearly parallel to the strike of bedding plane, that is, they run nearly horizontally. Such slickensides are occasionally present in the arched part of an anticline. It is well known that an anticline usually presents a more or less broad crest. Only in this broad part the upper bed has undergone a shear in the horizontal direction over against the lower one when a series of beds is folded. Consequently, horizontally lying slickensides are produced on the bedding plane due to this shearing movement. Thus when we notice horizontal or nearly horizontal slickensides on the bedding plane we may take the measurement of the dip angle of the bedding plane as the pitch of the folding axis even if no complete fold is observable.

EXPLANATION OF PLATES

Plate I.

Figs. 1-4. Indirect methods determining the strike of bedding plane. Fig. 1. Joints; Fig. 2. Mud-cracks; Fig. 3. Depression in limestone; Fig. 4. Flow of streams.

Fig. 5. Plan of a pitch-folding as measured near Nideggen in Schiefergebirge taken as an example for illustrating the relation of fracture cleavage to the foldings.

Fig. 6. Fracture cleavage in a symmetrical fold.

Fig. 7. Fracture cleavage in an overturned fold.

Plate II.

Figs. 1-7. Determination of fold-limbs by minor structure.

Fig 1. A closed fold.

Fig 2. An overturned anticline illustrating the relation between fracture cleavages and its limbs.

Fig. 3. Left limb of an overturned anticline.

Fig. 4. Right limb of an overturned anticline.

Figs. 5 & 6. Arrow indicates the direction of sliding along the bedding plane as revealed in slickensides.

Fig. 7. Cr.=cracks, sp.=splits with filling displaced by the folding.

Plate III.

Fig. 1. Pitch and direction of the axis of a fold determined by the fracture cleavage.

Fig. 2. Pitch and direction of the axis of a fold determined by the slickenside.

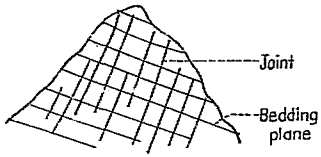

Fig. 1.

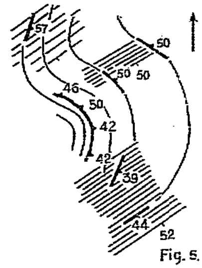

Fig. 5.

/40 Strike and Dip of Bedding plane

///50 Strike and Dip of Fracture Cleavage

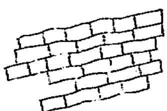

Fig. 2.

Fig. 3.

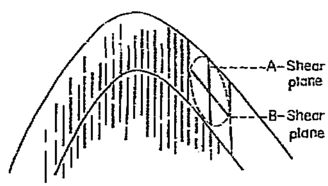

Fig. 6.

Fig. 4.

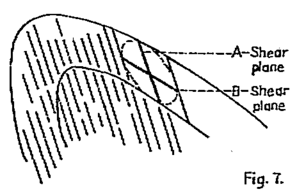

Fig. 7.

Fig. 1.

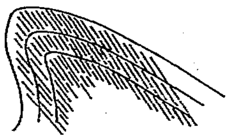

Fig. 2.

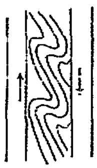

Fig. 3

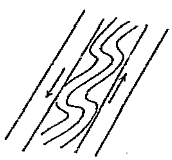

Fig. 4

Fig. 5.

Fig. 6.

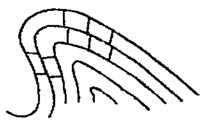

Fig. 7.

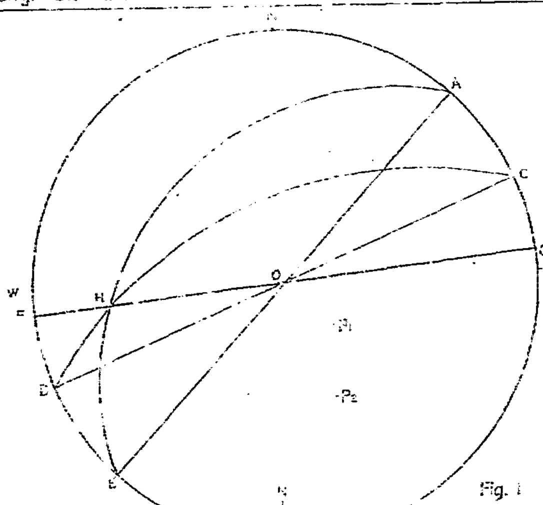

Fig. 1

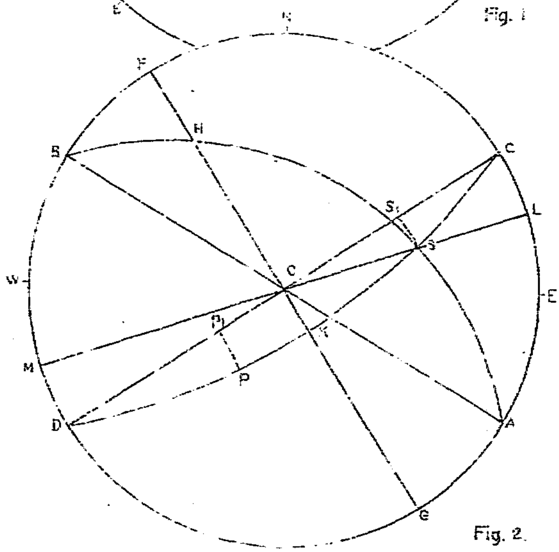

Fig. 2.

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On the Occurrence of Pre-Sinian Volcanic Series and Related Intrusive Rocks in the Vicinity of Fulin, Sikang*

By

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(Geological Survey of China)

With 3 Plates

CONTENTS

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I. INTRODUCTION

During the geological reconnaissance in E Sikang in 1941-1942 the writers observed an old acid volcanic series, together with related intrusive rocks, in the southeastern part of the province, mainly in the valley of the Tatuho (Tungho)[1]. In 1930, the extrusive rocks of this valley between Tsutati (Anshunchang)[2] and Chinkouho[3] first received[4] the attention of K. Krejci-Graf, who regards them as porphyry; but gives no detailed petrographical description [14, p. 420]. Although they are grouped together with the true intrusive type under the general term of granite by H. C. Tan and C. Y. Lee in their "Atlas for the Geology of Szechuan Province and Eastern Sikang" [20, sheets 22 & 23], specimens of rhyolite have been found among their collection from the same valley by C. C. Chang [5, p. 298-299]. In his recent reconnaissance in the same region L. C. Ch'ang erroneously considered this igneous complex to be exclusively intrusive [7, p. 13-14]. Some parts of the volcanics and associated intrusive rocks have, in fact, been noticed by those pioneers just named, but it is through the writers' field work as well as research in the laboratory that they are known to be products of a period of extensive igneous activity, which covered a fairly large area and gave rise to various types of rocks, often slightly sheared by later stress.

The age of the volcanic series and related intrusions has long been a matter of debate. Tan and Lee considered them to be Early Tertiary; Krejci-Graf regarded them as pre-Permo-Carboniferous; and Ch'ang assigned them to post-Jurassic—pre-Cretaceous. This disagreement is partly due to misinterpretation of some characters of the igneous body and partly due to an incomplete knowledge of the nature of the contact between it and the overlying sediments. However, the writers believe it to be of pre-Sinian age, a fact strongly supported by both stratigraphical and palaeontological evidences.

The area which forms the subject of this paper is Fulin[5] and its environs. Other outcrops will be deferred to a later article. Fulin is a market-town situated on an alluvial plain just on the northern side of the Tatuho, where a tributary called Liushaho[6] comes to join the latter and the newly built Loshan-Sichang Highway[7]

1. 大渡河（銅河）; 2. 紫打地（安順場）; 3. 金口河.

4. Legendre visited the same region and published a preliminary report on the geology thereof [Legendre et Paul Lemoine: Principaux résultats géologiques de la Mission Legendre au pays Lolo (Setchouan, Chine), Bull. Soc. Géol. France, 4 sér. t. 10 p. 307, 1910].

5. 富林; 6. 流沙河; 7. 樂西公路;

passes by in a NE-SW direction following the main stream. The volcanic series and related intrusions are found in a narrow belt from this place west-south-westward to Laoputzu[1] (see Pl. III). The geological features described in the following pages were observed during a six-day reconnaissance in this area, working mainly along the trails on both sides of the Tatuho. Special sections will be devoted to petrography and natural history of these rocks; their distribution and correlation with possible equivalents in the neighborhood, will also be discussed.

II. THE STRATIGRAPHICAL SUCCESSION

The geological section of the Fulin area along the northern side of the Tatuho valley is fairly complete. The different formations observed are arranged in ascending order as follows:

1. Pre-Sinian Volcanic Series. Reddish and greenish grey rhyolites and subordinate rhyolitic agglomeratic breccia and tuff. A detailed section of this series will be given later.

——————— Unconformity ———————

2. Sinian limestone. Grey dolomitic limestone with chert bands and concentric structures. A basal arkose of rhyolite and granite fragments is locally developed. Thickness about 500 m.

——————— Disconformity ———————

3. Cambro-Ordovician limestone and quartzitic sandstone. This formation may be divided into two parts: the lower is a comglomeratic quartzitic sandstone and silicious limestone and the upper a quartzitic sandstone and interbedded shales. From the upper sandstone *Cruziana*[2] was found, indicating an Ordovician age [22, p. 75-80]. Thickness over 200 m.

——————— Unconformity(?) ———————

4. Devonian limestone (?). Dark grey partly crystalline limestone with poorly preserved simple corals and *Productella*?[2]; upper part unexposed.

5. Permian Chihsia Limestone. Dark grey partly crystalline limestone with chert bands and nodules, yielding distorted fossils such as foraminiferas and gastropods; about 50 m.

6. Permian Omeishan Basalt. Dark green basalt with abundant phenocrysts of light grey feldspar, about 1.5×0.4 cm in size, showing amygdaloidal structure. Thickness less than 20 m.

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1. 老堡子.

2. Thanks are due to Dr. T. H. Yin for his kindness in identifying these fossils.

7. Rhaetic Hsiangchi Coal Series. A series of black and grey shales and brownish sandstone with local basal conglomeratic arkose, containing *Neocalamites* sp[1]., and other plant fragments; more than 80 m.

From the above description it is probable that the volcanic series is of pre-Sinian age. It seems, however, necessary to be pointed out here that although the basal arkose of the Sinian limestone appears to rest unconformably upon the volcanics, their actual contact is unfortunately obscured by superficial covering[2]. At any rate, the arkose itself suffices to prove the existence of an erosion surface between the volcanic series and the Sinian limestone. In connection with the erosion surface, mention must be made of the fact that at Sutsunpa[3], Papai[4] and elsewhere the volcanic series and related intrusive rocks are overlain by the Hsiangchi Coal Series, which has also a basal conglomeratic arkose about 20 m thick as briefly described before. In view of its material chiefly of subangular fragments of quartz-porphyry and granophyre and subordinately limestone and rhyolite, obviously derived from the rocks immediately below, the arkose must signify a physical break between the igneous complex and the coal series. But this erosion surface involves a much longer time and has done much more destructive work as compared with that between the Sinian and the igneous complex just mentioned. Thus these two surfaces are of similar nature but of quite different chronological significance.

III. DETAILED DESCRIPTION OF THE VOLCANIC SUCCESSION

The extrusive rocks are well-developed between Hochangpa[5] and Tachung[6] and to a less extent at Tsaiyangchi[7] and Laoputzu. As guided by the marked flow banding of these rocks and their variation in the structure and texture in successive beds, the time sequence of the eruption may be worked out to a rather accurate degree. But owing to bad exposure and disturbance by later intrusions it is hardly possible to trace the succession of the volcanic series from base to top. The section observed from Kuanyinyen[8] to Tsingkangtsui[9] is perhaps the most typical, where the volcanics generally strike in the direction of ENE-WSW and incline mainly to SE at angles

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1. The determination was made on drawings of the specimens by Dr. H. C. Sze, to whom the writers are much indebted.

2. The arkose is about 10 m thick and shows distinct bedded structure, dipping to S15°E at 20°. It is separated by a talus deposit about 20 m broad from the volcanics the flow banding of which inclines to N24°W at high angles, and by an alluvial fan of 70 m wide from the Sinian limestone which dips to N65°-85°E at 10°. The latter is clearly seen to overlie concordantly on the arkose further up-slope at a short distance, while the unconformable relation of the volcanic series with the limestone may be deduced from their angular contact.

3. 蘇村壩; 4. 八牌; 5. 火場壩. 6. 大中. 7. 菜秧溪 8. 觀音岩, 9. 青岡嘴.

varying from 35° to 90°. The following beds are observed as one proceeds from Kuanyinyen east-southeastward (see Pl. III) and most probably represent an ascending order.

1.	Dark red nodular rhyolite with scattered spherulites (ES 330, ES 330a, ES 330b)[1]	160 m ±
2.	Dark grey rhyolitic agglomeratic breccia	240 m ±
3.	Black and dark red glassy rhyolite (ES 328)	50 m ±
4.	Rhyolitic agglomeratic breccia with fragments chiefly of 3 (ES 328')	150 m ±
5.	Dark red rhyolite with scattered phenocrysts of feldspar and quartz and fragments of rhyolite, showing marked flow structure (ES 326)	800 m ±
6	Pale greenish grey glassy rhyolite showing pronounced banded structure (ES 327)	40m ±
7.	Red rhyolite with dull grey thin bands and abundant irregular pale grey patches (ES 325)	60 m ±
8.	Red rhyolite with abundant phenocrysts of feldspar and quartz, showing faint flow structure (ES 324)	300 m ±
9.	Dark red rhyolitic agglomeratic breccia with plentiful rock fragments in a sub-parallel arrangement (ES 324')	200 m ±
10.	Pale greenish grey rhyolite with a few rock fragments of rhyolite and small phenocrysts of feldspar and quartz (ES 323)	50 m ±
11.	Dark red rhyolite with scattered large red rhyolite fragments and abundant phenocrysts of feldspar and quartz (ES 322)	50 m ±
12.	Red rhyolitic tuff with small phenocrysts of feldspar and quartz, containing abundant fragments of very small size(ES 316, ES 317)	30 m ±
13.	Black rhyolite rich in phenocrysts of subrounded whitish feldspar and quartz, containing a few rhyolite fragments (ES 321)	100 m ±

Suppose there is no repetition of beds in the above section, the thickness of the volcanic series exposed at this particular locality would then amount to more than 2230 m. While rhyolitic lavas make up a little over 73% of the outcrop in linear measurement, pyroclastic rocks total about 26%. In view of its enormous thickness estimated, the volcanic series must have a great areal extent and a huge volume. Furthermore, owing to the abundance of pyroclastic rocks, the deposits observed might have been heaped up near the orifices, which will probably be discovered by extensive exploration in the future.

1. Numbers in parenthesis refer to specimens collected.

IV. INTRUSIONS

At Tachung the volcanic series is replaced by a red biotite-granophyre, which has much greater extent than the former, measuring about 3.5×10 km in dimension. The changing over from one to the other is insensible and the junction between them is quite irregular. In spite of this, the marginal flow banding of the granophyre, however local it may be, is suggestive of its younger age than the volcanic series, although the time interval was by no means long. At places, rhyolite xenoliths are found scattered in this rock, further indicating their time relation as just mentioned.

Near the village of Sutsunpa a grey quartz-porphyry comes to appear in an irregular but distinct contact with the granophyre, showing neither chilled border nor metamorphic effects. Thence southwestward, although these two intrusions crop out alternatively, the porphyry is in great excess of the granophyre in extent. At occasions, the porphyry is found to contain scattered red patches, which are petrographically like the former but distinguished by their attractive color. Since they are considered to be fragments of rhyolite, the porphyry seems to be geologically younger than the xenolith-forming rocks. But judging from the nature of the contact between these two intrusions as stated immediately above, they are most likely two differentiated members of the same parent magma; thus the interval between their implacement might be so short as to be negligible.

Rocks of dyke phase are small in extent and few in variety in the area under study. Apart from a few small bodies of granitic aplite in the volcanic series the dykes seem to be confined to the granophyre, all having limited size. While the granitic aplite is lithologically very like the granophyre, an additional fact indicating the younger age of the granophyre than the volcanic series, the dykes in the granophyre are predominantly of basic composition, including diabase and lamprophyre.

Owing to their genetic relation with the volcanic series, the determination of the age of the intrusions seems to be an easy undertaking. As seen at a distance the ranges of mountains composed of the intrusive rocks along both sides of the Tatuho River are capped chiefly by the Sinian limestone, in the same manner as in the area of the volcanics. Their contact has not been actually traced owing to inaccessibility of the steep cliff, with the exception of the Chuansintien[1] section in which the Sinian limestone was found to possess a basal conglomerate chiefly of pebbles of red granophyre and grey quartz-porphyry. It is thus evident that the intrusions as well as their related volcanics are of pre-Sinian age.

1. 穿心店.

V. STRUCTURAL FEATURES

The igneous complex of the present area seems to form a complicated anticlinorium with the intrusions as core and the volcanic series lying above the latter. The flow planes and bedding planes of the volcanic rocks generally strike NW-SE or NE-SW and dip to SW or SE or still NW at various angles from 30° up to 90°. It is partly unconformably capped by a partially preserved flat anticline composed of Sinian limestone in the axial part and with the Sinian, Cambro-Ordovician, Devonian (?) and Permian rocks successively exposed on its eastern limb. In the western part of this region, further unconformably superimposed on the two structural units just named, is a roughly N-S trending open syncline composed of the Jurassic coal series, the erosional interval prior to which has disfigured the western limb of both the anticlinorium and the gentle anticline. Apart from these structural disturbances there are two thrusts of considerable magnitude. One is found to the west of the alluvial plain around Fulin with its thrust plane inclining roughly to SW and bringing the Cambro-Ordovician rocks to rest on the probable Devonian formation. The other occurs at Chuansintien and strikes NNE-SSW, rendering the Sinian limestone to overlie the Jurassic coal series. While the latter is undoubtedly post-Jurassic, the former may also have been formed comparatively recently.

VI. PETROGRAPHY

1. Intrusive rocks.

Biotite-granophyre. This is a group of porphyritic rocks in red color with various shades of green and yellow. The conspicuous phenocrysts include quartz about 3 mm across, not infrequently showing well-formed hexagonal pyramids, and pinkish feldspar up to 4 × 11 mm in size, set in a fine groundmass (ES 331, ES 332, ES 334, ES 336). Dark minerals are very rare, the most common one being biotite. Under the microscope the greater part of this rock consists of a fine-textured base of quartz and feldspar, showing pronounced granophyric intergrowth of varying coarseness (Pl. I, Fig. 1). Subspherulitic structure (ES 336) and myrmekitic intergrowth (ES 331) are also noticed. The myrmekite is very fine and delicate and takes the wart-like form [18], growing at the expense of potash feldspar, which is usually bordered by primary plagioclase. The phenocrysts are corroded quartz and slightly turbid feldspars, which comprise, in the order of abundance, orthoclase, perthite and oligoclase. The plagioclase is usually twinned on the albite law, but pericline twinning is not infrequently noticed. Perthite is a characteristic constituent of this rock. It is chiefly the vein type in which fine irregular veinlets of untwinned albite are distributed throughout the orthoclase in a sub-parallel trend. It is probably of replacement origin, formed by circulating sodic solutions through contraction cracks [3, p. 150-151]. Flakes of dark green biotite with inclusions of zircon granules are the chief ferro-magnesian mineral, but in a small amount. A little idiomorphic yellowish green hornblende is occasionally present. Chloritic patches are often noticed, especially in the neighborhood of biotite. Euhedral and granular epidote occurs in abundance in some slices in which the myrmekitic structure is developed. Magnetite and a little apatite and sphene are scattered in the ground.

Quartz-porphyry. It is a porphyritic rock with sub-round phenocrysts mainly of quartz, about 2 mm in diameter, set in a fine-textured base. It is usually grey in color with shades of blue and green. The microscope reveals that the bulk of the rock consists of a microcrystalline groundmass, often crowded with wisps of sericite and occasionally exhibiting micrographic intergrowth (ES 342). While patches of mosaic quartz and feldspar are noticed in the groundmass in some slices (ES 342, ES 344), grains of quartz in triangular from occur in a considerable amount in others (ES 346). Phenocrysts are essentially corroded and embayed quartz, together with subordinate orthoclase and a little perthite and acid oligoclase or albite. The quartz often shows strain-shadows and at times are crushed to such an extent as to be broken, or even slightly ground, while the feldspars are usually decomposed with the production of sericite. A little biotite is present, but partly altered into chlorite. Accessory minerals are chiefly apatite, zircon and magnetite.

The red xenolithic patches occasionally found (ES 346) are lithologically similar to their host in many respects, but differ from the latter in that they contain a large amount of brown allanite and yellowish green epidote in aggregated grains and crystals and in that patches of aggregates of quartz occur sporadically in the microcrystalline groundmass, which shows flow banding as marked by variation in grain size. It thus becomes evident that the patches are most probably fragments of rhyolite which have undergone epidotization and silicification to a considerable extent, undoubtedly related to the action of magmatic emanations from the invading quartz-porphyry.

Minor intrusions. Two groups of dyke rocks are recognized, *i.e.*, diabase (ES 368) and quartz-hornblende-lamprophyre (ES 335). The former is a dark green fine-grained rock with shades of grey and brown. It is composed chiefly of lathshaped plagioclase enveloped by ophitic plates of hornblendic pseudomorphs of augite. The plagioclase shows a few albite-lamellae and marked zonal structure; but owing to deep decomposition it cannot be determined with certainty. The hornblende is pleochroic, with Z=green, Y=dark yellowish green, X=greenish yellow, and $Z>Y>X$, and shows $Z \wedge c'=19°$. A noteworthy amount of quartz possibly of secondary origin is found occurring interstitially and often well corroded. Magnetite in well formed skeleton crystals is of frequent occurrence. The hornblende-lamprophyre is a black aphanitic dense rock with a few oval cavities filled up with dark green material. Microscopic study shows that the rock consists essentially of tabular and occasionally square crystals of plagioclase in sheaf-like grouping and yellowish green chloritic pseudomorphs of idiomorphic hornblende. The plagioclase is infrequently twinned on the abite law, but often shows zonary banding, the interior of which is usually much decomposed with the production of calcite and a little chlorite. Both orthoclase and quartz are frequently met with, occurring in interstitial grains and in considerable abundance. A little brownish green biotite is present, fringed with a zone of green chlorite. Granules of iron ore occur in a large quantity throughout the whole area. As accessory minerals are fine needles of apatite and a little sphene. The cavities are composed entirely of chloritic substance.

2. Rocks of the volcanic series

As already described, the pre-Sinian volcanic series is exclusively of rhyolitic nature, showing great diversity in appearance and structure, even within the limits of a handspecimen. An examination of more than 80 thin sections shows that their microscopical features are equally varied but that the variation is confined to a definite range of crystalline structures and a limited number of mineral constituents. Merely on the basis of the megascopical and microscopical characters, the volcanics may be grouped into five categories, *i.e.*, (1) porphyritic rhyolite, (2) glassy rhyolite; (3) nodular rhyolite; (4) rhyolitic agglomeratic breccia; and (5) rhyolitic tuff; and will be described separately as follows.

Porphyritic rhyolite. This rhyolite is dull red in color and has a lithoidal groundmass with scattered small phenocrysts of quartz and red feldspar up to 3.5 and 2.5 mm long respectively, showing pronounced flow structure marked by light red streaks or lamellae about 1.5 mm wide (ES 319, ES 320). At occasions, irregular fragments of rhyolite of small size are found embedded in the rock. A modification is a black, dense, semi-vitreous rock, containing much more sub-round phenocrysts of light grey feldspar and whitish quartz and a few grey rhyolite fragments over 1.2 × 1.5 cm in dimensions (ES 321). Microscopically, the bulk of the rock consists of a microcrystalline to cryptocrystalline groundmass, often enclosing numerous crystallites chiefly of margarites, arranged in sub-parallel rows and sweeping around the phenocrysts (Pl. II, Fig. 1). Superimposed upon the crystallites and following the direction of flow are bands of closely packed microspherulites. In some cases, myrmekite-like intergrowths are well developed in the ground (ES 321) (Pl. I, Fig. 2) in which granules of epidote occur, probably genetically related to the myrmekitic structure. The phenocrysts include quartz and feldspar. The quartz is usually corroded and embayed with inlets of groundmass, often containing glass-cavities. Faint wavy extinction is frequently noticed in the quartz, more marked in large crystals than in the small ones. The feldspar comprises orthoclase (chiefly sanidine), perthite, oligoclase and microcline, all having been more or less decomposed. The oligoclase is twinned on the albite law, occasionally having its twinning lamellae bent. In that slice in which the groundmass shows myrmekite intergrowth (ES 321), both alkaline feldspar and plagioclase are partly replaced by epidote. The ferromagnesian mineral is represented by a green biotite, occurring in small flakes and limited quantity, but chlorite is much common. Granules of iron ores are frequently seen. A little zircon and apatite are also present.

Glassy rhyolite. This is a red and greenish grey lithoidal nonporphyritic rock, sometimes with a few minute phenocrysts of quartz and red feldspar, often showing banding structure marked by parallel dull red bands of variable width ranging from a fraction of one millimetre to several centimetres or by discontinuous green streaks of chloritic substance. Under the microscope the rock is very fine-textured, showing distinct flow structure due to variation in the grain size and amount of iron oxide dusts or other dark colored amorphous material. The groundmass is usually traversed by microperlitic cracks, indicating that the rock was originally of glassy nature and that the crystalline structure of the rock in which they occur is due to devitrification (Pl. I, Fig. 4) [1]. The phenocrysts are chiefly rounded and embayed quartz and subordinately corroded turbid orthoclase, perthite and albite. The quartz shows strain-shadows and occasionally contains parallelly aligned fluid inclusions. Minute flakes of dark green biotite are of frequent occurrence; a little dark brown to pale brownish green hornblende is also seen, giving $Z \wedge c = 16°$. Optically positive chlorite is common, often as decorations either on the perlitic fissures or flow layers.

A few epidote granules occur interstitially. Wisps of sericite derived from feldspar are frequently noticed in the groundmass. A little zircon, rutile and magnetite appear.

Nodular rhyolite. It is a dull reddish devitrified glassy rhyolite with shades of green and yellow, showing well developed nodular structure and indistinct flow banding (ES 330, ES 330a, ES 330b). The nodules are sporadically distributed in the rock, seeming independent of the flow structure, and generally assume spherical or subspherical form, ranging from a few millimeters up to 3.5 cm in diameter. Triangular and polygonal shapes are also noticed. They are mostly composed of whitish quartz in the central portion and red feldspar in the exterior, either in roughly concentric arrangement or in irregular intergrowth and often stained by chloritic material. In some cases, a single nodule consists of two or more spheres. At occasions, red feldspar is the only constituent of the spherulite (Pl. I, Fig. 5). The mineral composition and microscopical features of this rock are similar in many respects to those of the glassy rhyolite described above, but a great diversity in texture is recognized. It is essentially a microcrystalline mass, together with patches of aggregated grains of quartz and feldspar, indicating "patchy devitrification" [4]. Perlitic cracks are well developed in the matrix, usually encircling mosaic quartz and turbid orthoclase. The quartz contains parallelly aligned crystallites and shows wavy extinction (Pl. I, Fig. 3). Patches of chloritic substance occur in abundance, usually decorating the perlitic cracks. Some portions show granophyric structure. Spherulitic structure is fully developed in the groundmass which will be detailed below. Only a few crystals of quartz and sanidine and acid oligoclase occur as phenocrysts; the quartz is well corroded and embayed with inlets of the groundmass, usually showing strain-shadows. Flakes of biotite in a pale yellowish green color are the chief ferromagnesian mineral, but optically positive chlorite is more common, showing strong pleochroism, X=pale green, Z=Y=dark green, $X<Z=Y$. A little greenish brown hornblende is present. In one slice (ES 330a) patches of pinkish isotropic allanite occur, exhibiting imperfect cleavages and moderate refringence. Apatite and iron oxide are the chief accessories.

The spherulitic growths may be divided into two main groups: one developed in the groundmass and the other in the nodules. The former is of microscopical dimensions in complete or partial development and distinct but irregular form. They are distributed at random throughout the matrix, but mostly well developed along the perlitic cracks (Pl. I, Fig. 3), tending to coalesce into bands. The radial feldspar fibers which constitute the spherulites usually form broad black cross between crossed nicols owing to splitting into many divergent black arms. Although the second group has the same fibrous structure as that of the first one, the growths vary greatly in structure. In general, the nodules are composed of two layers, *i.e.*, the inner mosaic quartz and the outer fibrous feldspar with a continuous outline or divergent branches. The feldspar fibers, nearly parallel to which lies the direction of vibration of the fast ray, show parallel extinction or very small extinction angles and then may be crystals of sanidine elongated along *a*-axis. Owing to variable orientation of the fibres, the extinction of light is quite irregular and no black cross is formed. The fibers do not uniformly radiate from the center of the spherulite but end wherever to meet the area of quartz. The course of the fibers is often interrupted by circular lines so as to separate the spherulite into concentric layers, probably marking the original outline from which successive layers of the fibers have grown out (Pl. II, Fig. 5). In some cases, closely packed indistinct minute circles appear to dot the area of feldspar fibers, having lower refringence than that of the latter, which continue, however, their course without change of direction (Pl. II, Fig. 5). It seems likely that they are minute spherulitic bodies, later superimposed by the larger ones. In other cases, just as the shells of some lithophysae [13, p. 417], the fibers are further interposed by small pellets of tridymite, which differ from the minute spherulites in their well defined outline and being not traversed by the fibers (Pl. II, Fig. 6). Some spherulites have only one center, while others consist of two or more coalesced ones so that the arrangement of the radial fibers shows an undulatory appearance (Pl. II, Fig. 2). In case the nodules are composed entirely of feldspar, the spherulites take quite irregular forms, such as hemisphere, sector, etc. The fibers usually occur in wedge-shaped groups (Pl. II, Fig. 7), branching out in such a way that the parts of the following branches are more numerous and divergent than the preceding ones, a phenomenon long recognized by J. P. Iddings [13, p. 415]. Owing to the great variation in orientation of the crystals thus formed, the fibers do not extinguish uniformly with the production of black cross between crossed nicols.

Rhyolitic agglomeratic breccia. This group is next in abundance to the rhyolite lava and represented by at least three varieties. The first one is crowded with angular fragments of glassy rhyolite, black and dark red in color and varying from 0.1 to 2.5 cm in diameter (ES 328). Owing to loose cementation, crevices and cavities may be considerably large. The matrix is pale greyish green in color and fine-textured, containing a few crystals of quartz and red feldspar. The second variety (ES 324) is a dark red *lithoidit* and characterized by the sub-parallel arrangement of the enclosed rock fragments, which vary both in size and in form and appear to have drawn out along the direction of flow. A fairly large amount of phenocrysts, mainly of red feldspar crystals and quartz grains, occurs. The third modification (ES 369) has not been found *in situ* but occurs in the talus deposit near the village of Laoputzu, consisting essentially of sub-angular rock fragments up to 5 cm in length, embedded in a pale green and fine-textured base. The slices show that the groundmass of all these types is micro- to cryptocrystalline, displaying tortuous flow banding and stained by chloritic material and iron oxide. In some cases, numerous crystallites, chiefly trichites and scopulites, occur in the mass. The enclosed rock fragments are mainly devitrified rhyolitic glass as indicated by the perlitic cracks (Pl. II, Fig. 3). Minute volcanic lapilli occur also in abundance, showing typical "ash structure." Crystals of corroded quartz and orthoclase and a little oligoclase are frequently noticed. Ferromagnesian minerals are very rare, usually represented by a green biotite and chlorite.

Rhyolitic tuff. Megascopically this is a red compact fine-textured rock with plentiful small rock fragments about several millimetres across and crystals of quartz and red feldspar, which are distributed at random so as to give rise to a dirty appearance (ES 361, ES 361a, ES 362). The slices show that the rock is quite heterogeneous, composed partly of sub-angular rhyolite fragments and partly of shreds of devitrified glass. The latter vary greatly both in size and in form, but mostly possess concave outlines, showing the characteristic "ash structure" (Pl. II, Fig. 4). Partly rounded and broken crystals of turbid orthoclase and albite and quartz occur also in abundance. All these are set in a microcrystalline, occasionally laminated, matrix heavily charged with dark red iron dust and wrapped round by the lamination of the latter. Mafic mineral is in a negligible amount and represented by a decolorized biotite.

VII. LATER MODIFICATIONS

From the petrographical description given above, it will be seen that the volcanics and intrusive rocks have undergone various modifications since their "eruption." Among them the most noticeable changes fall into two types, namely, (1) deuteric effects and (2) mechanical deformation. They differ greatly from each other, not only in nature but also chronologically. These alterations are by no means detectable in all the rock types observed and have not been equally developed even within the limits of a single handspecimen. The factors governing such variations are chiefly the physico-chemical conditions under which a certain rock or mineral is subjected to the changes; and will be seen where they come to appear in the folllowing remarks. In addition, the process of devitrification may be dealt with under this heading, but it is confined exclusively to the glassy rhyolites as shown by the microcrystalline structure and the formation of crystallites and irregular mosaic of grains of quartz and feldspar. The most convincing evidence of this is afforded by the preservation of perlitic cracks in the crystalline base of these rocks.

(1) *Deuteric effects.* The term "deuteric" of J. J. Sederholm [18, p. 142] used here designates such end-stage changes redefined by R. J. Colony [11] as albitisation, epidotisation and chloritisation. The phenomena are confined mainly to the biotite-granophyre and subordinately to the rhyolitic lava, but rarely noticed in the quartz-porphyry. They are manifested by mineralogical changes in the manner of replacement accompanied by micro-structures. Among them albitisation is the most remarkable and widespread as indicated by myrmekitic structure and perthitic intergrowth. However, it must be pointed out that although the latter is largely of the vein type probably formed by replacement, the occurrence of varieties of exsolution origin in the rocks should not be excluded owing to the fact that the perthite is occasionally too fine and delicate to be accurately discerned. While chloritisation of biotite and other ferromagnesian minerals is universal, the formation of epidote from materials derived during the alteration of the feldspar and mafic minerals or from some outside source, often accompanied by the myrmekitic intergrowth [2, p. 65], is only of rare occurrence. Doubtlessly the agents responsible for such modifications are magmatic emanations; it is a question whether the fluids were derived from a certain common source or given off respectively from the magmas which produced the various rocks under discussion. Since these changes are paulopost and the rocks affected represent two phases of an igneous activity, *i.e.*, intrusive and extrusive, with a certain period of interval, the second alternative seems probable.

(2) *Mechanical deformation.* Both the volcanic and intrusive rocks have been slightly affected by stress of some kind as mentioned before. The effects thus produced are mainly those of strain without yielding as shown by the widespread undulose extinction of quartz. Besides, some fracture types are also noticed, such as the bending of plagioclase, the crushing of quartz grains, etc. Moreover the mechanical disturbance is occasionally accompanied by mineral transformations, which are illustrated by the formation of sericite and a portion of chlorite and more remarkably by saussuritisation

nd uralitisation of the basic dike-rocks. But near the western border of the region n question, both volcanic and intrusive rocks show more pronounced cataclastic phenomena; then, at Laoputzu, Anshunchang and elsewhere their metamorphic derivatives such as quartz-sericite-schist[1], sheared quartz-porphyry, flaser-granite, etc. are the predominant types[2]. The intensity of dynamic disturbance toward the west is highly significant, most probably suggesting the dislocation of the crust associated with such a metamorphism [17, p. 322-323] may have taken place somewhere in that region.

VIII. CORRELATION AND DISTRIBUTION

The extensive outburst and subsequent intrusion which have given rise to arious rock types of acid nature[3] in the area of Fulin occurred in the pre-Sinian ime. In view of the slight metamorphism by which they are affected, this igneous omplex is apparently incomparable to the crystalline rocks of this age in other parts of the country. However, such a discrepancy in nature may be appropriately ascribed to difference in physico-chemical environments once prevailed in different localities. Thus, relatively intensely metamorphosed types of the igneous complex equivalent to the slightly sheared ones occur in some places of the surveyed region due to certain tectonic conditions as previously mentioned.

Just like the igneous complex of the Fulin area, so the pre-Sinian granite of the well-known sacred mountain of Omeishan along the western border of the Szechuan Basin and about 100 km to the east of Fulin, also appears intact so far as metamorphism is concerned [8, 12, 19, 15]. In addition, the stratigraphy of this section is quite similar to that of the present region. Thus it becomes natural that the intrusions of these two localities may be duly correlated, although extrusive equivalent is lacking in the Omeishan area.

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1. Both field observation and microscopic study show that this rock is a metamorphosed rhyolite.

2. Petrographical description and comparative study of these rocks will be set forth in a separate paper.

3. Partial chemical analyses of three specimens representative of the type rocks have been made by Mr. Y. C. Shang of the Chemical Laboratory of the Survey. Their silica content is given in the following table:

Sample	Rock name	Percentage weight of SiO_2
ES 326	Rhyolite.	73.33
ES 331	Granophyre	76.27
ES 380	Quartz-porphyry	72.37

The igneous body composing the famous mountain pass Tahsiangling[1] about 30 km to the north of Fulin was mapped as a granite intruded into the "Red Beds" of Cretaceous age by Tan and Lee [20, sheet 22][2]. It is, however, discovered by the writers that the southern slope of this pass is made up of pinkish rhyolite and green agglomeratic rhyolite while a reddish coarse-grained biotite granite predominates in the northern. They do not exhibit any metamorphic phenomena other than strain-shadows in quartz, nor the overlying sediments show the least sign of thermal metamorphism. Owing to its close petrographical similarity and geographical proximity to the pre-Sinian igneous complex of Fulin, both the extrusive and intrusive rocks of Tahsiangling may then be assigned to the same age. According to the senior writer's observation made in 1939, the extrusive quartz-porphyry, rhyolite and agglomeratic lava occurring near Tachiaotou[3], Yungching[4], not far from Tahsiangling, are really the equivalent of the extrusives of the latter, consequently it may be reasonably inferred that they came into being during the pre-Sinian volcanic episode instead of Jurassic or Lower Cretaceous as assumed by C. C. Chang [6, p. 202].

The volcanic series in Luku[5], a considerable distance to the south of Fulin, was discovered by Y. C. Cheng and his colleagues in 1939 and considered as of pre-Permian age [9, p. 1-14], which was recently changed into pre-Middle Devonian [10, p. 256]. Judging from its geological features and petrographical characters as described by them and also observed by the writers themselves, the volcanic series of the said region is probably an equivalent of that dealt with in the present paper.

IX. CONCLUSIONS

1. The contribution of the present work is the establishment of a pre-Sinian volcanic series of rhyolitic composition accompanied by genetically related biotite-granophyre and quartz-porphyry and basic dykes[6] in the area of Fulin, E. Sikang. So far as the present knowledge goes, it is the oldest of its kind in this country.

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1. 大相嶺.

2. According to the pioneer work of L. von Loczy on this region in 1879, the igneous mass was an intrusive body composed chiefly of an amphibole-granite in the northern part and quartz-porphyry in the southern and belonged to the Archaean age [16, p. 680-685, fig. 121].

3. 大橋頭; 4. 滎經; 5. 瀘沽.

6. It is further observed that in addition to the acid rocks so far described, the igneous complex also contains basic and ultrabasic types as occurring at Tsaopapai and elsewhere. For the convenience of comparative study and geological mapping, the term "Fulin Igneous Complex" is proposed for them.

2. It is most probable that the pre-Sinian igneous activity under consideration has covered a fairly large area, mainly the southeastern part of Sikang and the borderland between the latter and the Red Basin of Szechuan.

3. Both the volcanic and intrusive rocks have usually been affected by later dynamic forces, but only the earliest stage of metamorphism has been attained.

4. As evidenced by its immediately overlying arkose, the pre-Sinian igneous complex has definitely been subjected to a long period of erosion. This erosion surface may represent the so-called "ep-Archaean interval," which is of almost universal nature and has long been recognized in various parts of the country [21, p. 65-82].

5. As the geographical position of the igneous body under question is just on the border between the Red Basin of Szechuan and Sikang, it is both geologically and palaeogeographically of high importance. It is a well-known fact that most sediments, if not all, deposited in post-Algonkian times in these two regions differ considerably. The most outstanding difference lies in the deposition of "Sikang Series"[1] in one region and its absence in the other. Such a sudden change in facies may be ascribed to an old landmass composed of the pre-Sinian igneous complex, which served as a barrier so as to render the environments of deposition on one side quite different from the other. However, the extension of this supposed land cannot be delimited for the time being and further work is thus desired.

In conclusion, the writers wish to express their gratitude to Dr. Y. C. Cheng for his constant zealous direction and helpful suggestions during the preparation of the paper and his kindness in critically reading the manuscript. Acknowledgment should also be made to Dr. T. K. Huang for valuable discussions and criticism for many points of the present work.

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EXPLANATION OF PLATES

Plate I.

Fig. 1. Granophyre (ES 334), Tachung, 41×. Showing micrographic intergrowth of feldspar (turbid) and quartz (clear). ‖ N.

Fig. 2. Porphyritic rhyolite (ES 321), Tsingkangtsui, 41×. Showing myrmekitic intergrowth. A crystal of epidote is found in the center of the drawing. ×N.

Fig. 3. Nodular rhyolite (ES 330), W of Kuanyinyen, 41×. Showing the groundmass with perlitic cracks, which enclose partial spherulites and patches of mosaic quartz. The latter contains crystallites and shows undulose extinction. ×N.

Fig. 4. Glassy rhyolite (ES 327), Tsingkangtsui, 41×. Showing parallel flow lines traversed by a system of curving perlitic cracks. ‖ N.

Fig 5. Sketch of a nodular rhyolite with various forms of spherulites, blank space=matrix, dotted area=feldspar, cross-hatched portion=quartz, from W of Kuanyinyen.

Plate II.

Fig. 1. Porphyritic rhyolite (ES 320), Tsingkangtsui, 41×. The cryptocrystalline groundmass shows flow structure marked by subparallel crystallites, which sweep around the embedded porphyritic quartz and feldspar. Between crossed nicols, bands of small spherulites occur along the flow-lines, which pass through the former without interruption. ‖ N.

Fig. 2. Nodular rhyolite (ES 330 a), W of Kuanyinyen, 5×. Showing a spherulite with several centers so that the arrangement of feldspar fibers gives rise to undulatory appearance. Trends of minute spherulites (small circle) and perlitic cracks are also developed. ‖ N.

Fig. 3. Rhyolitic agglomeratic breccia, (ES 324), Tsingkangtsui, 21×. Showing the subparallel arrangement of slightly elongated rock-fragments and shreds of glass. The former usually show perlitic cracks while the latter exhibit "ash structure". A few crystals of quartz and feldspar are enclosed. ‖ N.

Fig. 4. Rhyolitic tuff (ES 316 a), Tsingkangtsui, 27×. Showing typical "ash structure" as indicated by concave outlines of shreds of devitrified glass. Crystals of quartz and feldspar are also embedded in the matrix. ‖ N.

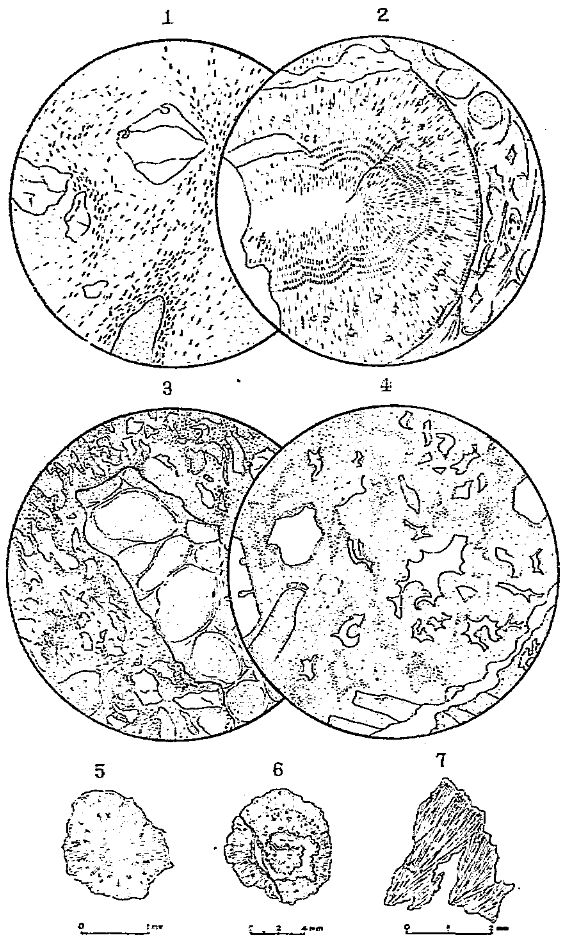
Fig. 5. Spherulite composed of feldspar fibers traversed by concentric lines and minute spherulites (ES 330), from W of Kuanyinyen. ‖ N.

Fig. 6. Spherulite made up of feldspar fibers in the exterior portion and mosaic quartz in the interior, together with minute pellets of tridymite (ES 330 b), from W of Kuanyinyen. ‖ N.

Fig. 7. A sector made up of feldspar fibers (ES 330 b), from W of Kuanyinyen. ×N.

Plate III.

Geological map of the Fulin area.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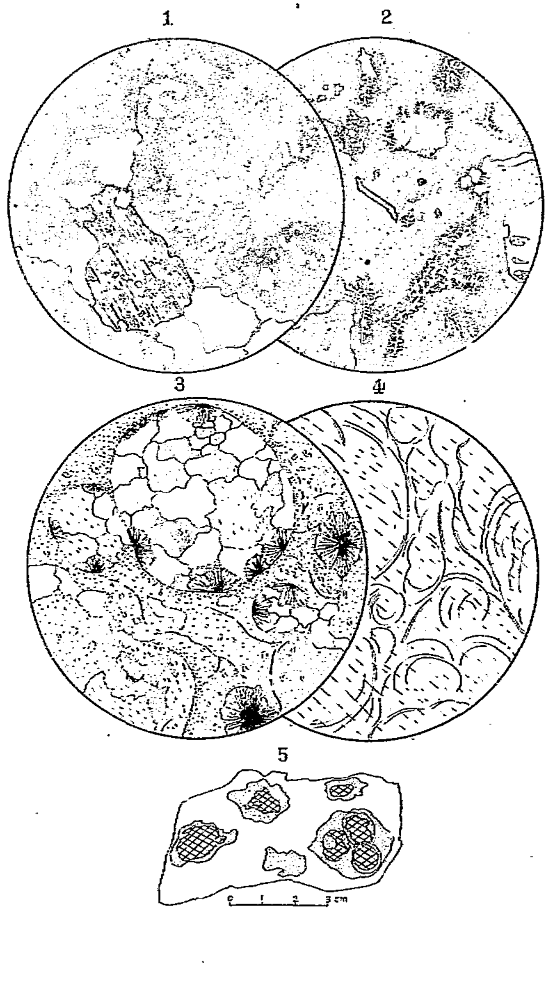
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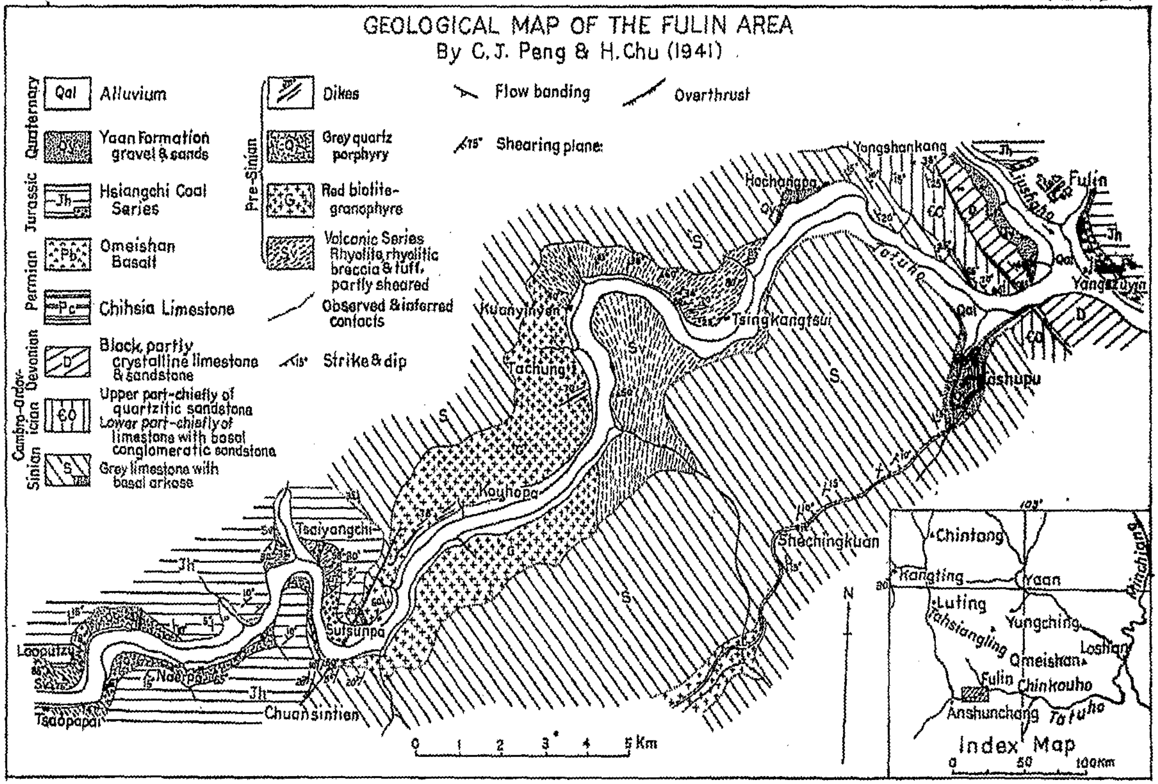
GEOLOGICAL MAP OF THE FULIN AREA
By C. J. Peng & H. Chu (1941)
Quaternary
Qal Alluvium
Q Yaan Formation gravel & sands
Jurassic
Jh Hsiangchi Coal Series
Permian
Pb Omeishan Basalt
Pc Chihsia Limestone
Devonian
D Black, partly crystalline limestone & sandstone
Cambro-Ordovician
CO Upper part-chiefly of quartzitic sandstone Lower part-chiefly of limestone with basal conglomeratic sandstone
Sinian
S Grey limestone with basal arkose
Pre-Sinian
Dikes
Q Grey quartz porphyry
G Red biotite-granophyre
Sv Volcanic Series Rhyolite, rhyolitic breccia & tuff, partly sheared
Observed & inferred contacts
Strike & dip
Flow banding
Shearing plane
Overthrust
Yangshankang
Hochangpa
Fulin
Liushaho
Tatuho
Yangtzuyin
Kuanyinyen
Tsingkangtsui
Tachung
Tashupu
Kouhopa
Tsaiyangchi
Shechingkuan
Sutsunpa
Loaputzu
Naerpa
Tsaopapai
Chuansintien
0 1 2 3 4 5 Km
N
Chintang
Kangting
Yaan
Minchiang
Luting
Yungching
Tahsiangling
Omeishan
Loshan
Fulin
Chinkouho
Anshunchang
Tatuho
Index Map
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BULLETIN OF THE GEOLOGICAL SOCIETY OF CHINA
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Notes on the Bauxite Deposits of Kueichou, with Special Reference to Their Variation in Quality*

By

C. J. PENG

(Geological Survey of China)

*With 2 Text-figures.

CONTENTS

I. INTRODUCTION

The discovery of bauxite from a number of places in Kueichou in 1941 made by Dr. S. S. Yoh and his colleagues [13] is of economic as well as scientific significance. In the following year, the writer, in collaboration with Dr. C. Y. Li, had an opportunity of making an investigation of the three deposits found, namely, Yunwushan[1], Wangbi[2] and Wangkuan[3]. Though a

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1. 雲霧山; 2. 王比; 3. 王官.

preliminary report dealing with geological and other details of the deposits was written by the writer right in the field, some problems have been left unsolved, the most interesting and also economically important one being their variation in quality.

The bauxite, for the most part of inferior quality, shows a great variety of chemical composition. Moreover, as a result of careful observation of a few sections in the field and detailed study of a number of specimens and slides in the laboratory, it is known that variation both in physical and in mineralogical characteristics is also remarkable. The variations appear to be much more pronounced in the vertical direction than in the horizontal and seem furthermore to bear a relationship to depth.

The purpose of this article is to give a brief account of the nature of the deposits, particularly the facts related to their vertical changes. Although the problem is attacked merely from a scientific standpoint without any practical considerations, the present contribution may be, it is hoped, of use for further exploration and development of the deposits.

II. THE AGE OF THE BAUXITE DEPOSITS

The bauxite is usually found to rest upon the Lower Ordovician siliceous dolomite[1], which yields *Proterocameroceras*. The contact between the Ordovician and the bauxite is unconformable on account of the uneven surface of the former. Obviously, the presence of bauxite is in itself also highly suggestive of this relationship owing to the fact that bauxite deposits represent weathering products of certain pre-existing rocks as generally accepted.

The stratigraphy of the bauxite-bearing rocks is given in ascending order as follows:

Subformation: Lower Ordovician siliceous dolomite with *Proterocameroceras* sp.[2] and crinoid stems. Thickness about 380 m.

__________Unconformity__________

Late Lower or early Middle Carboniferous:

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1. One analysis of the dolomite made by Mr. Y. C. Shang, chemist of the Survey, shows a composition as follows: $CaO=32.53$, $MgO=20.22$, $SiO_2=7.38$,

2. All fossils are identified by Dr. S. S. Yoh.

A. Bauxite beds:

(1) Ferruginous sandstone and bauxitic shale with a layer of hematite at the base. Thickness about 1 m.

(2) Greyish and pinkish bauxite and bauxitic shale. They are unfossiliferous, but the uppermost part is a dark brown carbonaceous bauxitic shale, occasionally containing plant remains too poorly preserved to be identified. Thickness varying from 3 to 8 m.

B. Coal Series: A series of variegated shales, whitish quartzitic sandstone and carbonaceous shale, infrequently with two or three thin anthracitic coal seams. Thickness from a few centimeters to 2.5 m.

Middle Carboniferous:

C. Huanglung Limestone: Light grey well-bedded limestone with a coral fauna including *Chaetetes* sp., *Zaphrentis* sp., *Caninia* sp. Thickness about 20 m.

____________Disconformity____________

Lower Permian:

D. Chihsia Limestone: Grey well-bedded limestone bearing numerous irregular bands of flint, occasionally with a layer of ferruginous quartzitic sandstone at the base. In the limestone the following species are found: *Nankinella inflata*, *Productus yangtzeensis*, *Michelinia* cf. *microstoma*, *Tetrapora elegantula*, *T. syringoporoides*, *Polythecalis chinensis*, *Wenzelella* sp., *Orthotoechia* cf. *morganiana*.

It is further observed that the bauxite layer passes upward without detectable physical break but with a transitional bed of carbonaceous bauxitic shale into the coal series. It may thus be regarded as a part of the latter. Since the coal series is immediately succeeded by the Huanglung Limestone, it is to be considered either as early Middle or as late Lower Carboniferous, which is likewise the age of the bauxite.

III. MINERALOGICAL AND CHEMICAL CHARACTERISTICS

The bauxite is a light grey and light yellow, fine-grained, compact mass and looks like lithographic limestone. The finer ore is denser and gives a smooth feeling, frequently showing sub-conchoidal fracture. Both oolitic and pisolitic strutures characteristic of most bauxites are not common in the present example. Only the relatively coarse variety often contains some scattered oolites and pisolites. The diameter of the largest pisolites seen is about 1 cm, while oölites are usually 0.1 to 0.15 cm across. Conglomeratic and banded bauxites have also been noted. A special feature of some specimens which has hitherto been unrecorded is the "vermicular" structure, shown by concretion-like masses and patches ranging from a few millimeters up to 1.8×1.5×3.5 cm in size (see Fig. 1). These bodies are translucent, bluish grey or brown and wax-like, and often assume a tubular form with rather sharp boundary.

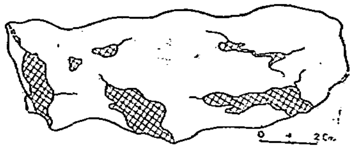

Fig. 1. Sketch-diagram of a "vermicular" bauxite (60T)[1].
White=matrix.
Cross-hatching="vermicular" tubes.

Although various forms of bauxite as just described have been recognized, only three kinds are of common occurrence, *viz.*, (1) the coarse "vermicular" and oolitic, (2) the fine "vermicular" and (3) the fine massive. All these forms are not only distinguishable morphologically, but also differ more or less from one another both mineralogically and chemically. Moreover, the quality of the bauxite is usually reflected by its external form; thus identification of various forms can often make it possible to estimate its grade.

1. *Mineral constituents.*

The bauxite is apparently homogeneous in composition, but microscopic study reveals that it is composed essentially of a dark colored "amorphous" mass, together with a minor amount of crystalline minerals. Among the latter the various species so far recognized are going to be described below.

Diaspore. This is by far the most common form of aluminum hydroxides found in the deposits. It is much more abundant in the fine massive ore than in the "vermicular" and coarse variety. It is usually irregularly granular and about 0.02 mm across. But crystals are also frequently seen, showing (010) face with incomplete (210) cleavages and terminated by unit pyramids (111). Partings nearly parallel to (001) are distinct and common. It is usually bluish or orange with various shades of green, yellow and grey and shows remarkable pleochroism, X=colorless, Z=yellowish grey to greyish blue and X<Z. The

1. The numbers and letter in the parenthesis refer to the specimen collected.

refringence is moderate but its birefringence is strong. It is optically positive with a large optical angle.

Boehmite? A few dark blue grains and prisms were found, showing indistinct cleavages parallel to X' and weak pleochroism with X<Z. The refringence is as high as diaspore, but the birefringence is much weaker. Judging by its resemblance in some respects to but differing in others from diaspore, this mineral is probably boehmite. However, it should be admitted that the determination is still questionable, since some characteristic features of this mineral as described by J. de Lapparent [5] have not yet been recognized.

Gibbsite. It is extremely rare. Only a few colorless plates have been found, giving $Z \wedge c = 42°$ and showing a refringence slightly higher than balsam.

Kaolinite. The "vermicular" bauxite, coarse or fine, usually contains a large amount of this mineral, whereas the fine massive ore is almost always poor in it. But in any case it is by far the most common crystalline mineral so far noted. It is found as flakes and sheaves enclosed in the amorphous base, distinguished by its low refractive index and birefringence and especially by its tendency to combine into fan-like or vermicular bunches. It is to be noted that it frequently shows wavy extinction and occasionally spherulitic structure.

Halloysite. It occurs in irregular patches and makes up the bulk of the "vermicular" tubes. Aggregated grains of this mineral are also frequently noted in other forms of the bauxite. It is essentially isotropic with N=1.546 as determined by Chaulnes method, but also contains scattered small particles with visible birefringence. Some particles exhibit well defined spherulites, giving a black cross between crossed nicols. The identification of this mineral may further be ascertained by its physical properties, such as $H \lessdot 2.5$ and sp. gr.=2.43 and its translucent character, waxy appearance and sub-conchoidal fracture as mentioned before. Since this mineral is, as a rule, apparently amorphous and isotropic, the formation of the crystalline structure might be due to internal strain resulted from contraction on drying. This may be verified by its less water content, 14.28[1], as given in Table IV, higher refractive index [6, p.12] and spherulitic structure [10, p. 519; 4, p.25] as stated immediately above.

1. This amount renders the halloysite to approach to kaolinite, which ordinarily contains 14% of water.

Zircon. It is of common occurrence in many samples and found as minute grains or occasionally as prisms. It is distinguished by its high refringence and birefringence.

Rutile. This is perhaps the chief titanium-bearing mineral, but only a few minute grains of it have been detected. It is well marked by its dark red color and extreme refringence and birefringence.

Sphene. A few dark brown oval grains with extreme birefringence may be sphene, but owing to the minute size the determination cannot be made certain:

Quartz. Only a little quartz is noted occurring in triangular or subangular grains. It may be identified by its rapid extinction or "quick wink" and clear appearence.

Pyrite. It was found only in the samples coming from the top and the lower portion of the Yunwushan section, where the coal series is well developed. It is the only mineral other than halloysite which can be recognized with the naked eye. It usually occurs in minute granules or cubes but is also found as nodules with a rim of carbonaceous material.

Limonite. Patches and streaks of limonitic material are not infrequently noted in most slices and the iron content of the bauxite may own its source to this mineral.

From an inspection of the above list of mineral association, it will be noted that diaspore is the preponderant hydroxide of aluminum, while gibbsite and boehmite (?) occur only as accessories. The abundance of kaolinite and halloysite is also a distinguishing feature of the deposits. It calls for special attention that in the "vermicular" bauxite there are much more kaolinite and halloysite than hydrates of alumina, whereas the reverse is true for the fine massive ore.

2. *Chemical composition.*

From the analyses of the writer's collection of 52 samples[1] taken from different localities in the three areas investigated, it is known that they show a remarkable consanguinity in chemical character, although some constituents usually

1. Thanks are due to the Huanghai Chemical Industry Institute for analysing this set of samples.

vary a little, sometimes considerably, in amount. This leads the writer to believe that the bauxite deposits must be originated from a common mother rock and formed by the same processes. For the sake of simplicity, the long list of analyses will be left out in the present paper; only some chemical characteristics will be given in the following:

Al_2O_3. Most samples have a low Al_2O_3 content, averaging to 45% and varying only a little. But some coming from the lower horizon of the Yunwushan section contain about 70% of alumina.

SiO_2. The silica content generally averages to 35% and may attain to 45%. Of those samples with about 70% of Al_2O_3, silica is reduced to 8% or less.

Fe_2O_3: The bauxite is always poor in iron and only 1% or less of Fe_2O_3 has been detected from all the samples: It is, however, worthy of notice that there occurs a layer of hematite with a ferruginous shale at the base of the deposits as stated before.

H_2O. The combined water of the bauxite is exclusively around 14.5%. This is one of the most distinguishing features of the bauxite.

TiO_2. TiO_2 runs about 2.5% in most samples, but may be as high as more than 7% in those which contain some 70% of Al_2O_3. It is to be noted that in many Indian bauxites more titanium oxide accumulates also in the aluminous portion of a laterite mantle [2, p. 27].

As seen from the above data, the ratio of $\frac{Al_2O_3}{SiO_2}$ for most samples analysed is about 1.5, although they have the profit of low iron content. It is thus clear that our bauxite deposits are principally of low grade and that the majority of them seem to be a bauxitic shale instead of a true bauxite ore suitable for extraction of aluminum.

A point worthy of special remark is that the forms of the bauxite bear a relation to chemical composition as close as to mineralogical character. The "vermicular" bauxite has always a SiO_2 content more than 30% with only about 40% of Al_2O_3. But the bauxite of good quality is mostly fine and free from "vermicular" tubes. The composition of the coarsely textured and massive variety is usually like that of the "vermicular" one.

3. *Mineralogical and chemical calculations.*

Since the bauxite consists mainly of an "amorphous" material, it is interesting and important to inquire into which form of aluminum hydroxide it would assume in conformity with its chemical composition. How much aluminum silicates (kaolinite and halloysite) actually exist in along with the hydrates of alumina in various forms of the bauxite also entails estimation and determination. In order to fulfil these objects, calculations of mineralogical composition from the data of analyses have been made. For the sake of comparison, analyses of two samples, representative of the fine "vermicular" and the fine massive bauxite respectively, have been chosen for the purpose. It is to be noted that the composition of the fine "vermicular" variety is not diverging far from the average described before. Thus its calculated mineralogical composition may be considered to be typical.

From the mineralogical study, it has been made known that free silica is very rare and all SiO_2 is nearly entirely combined in kaolinite and halloysite. Since the latter here found has nearly the same water content as kaolinite as already referred to, they will not be differentiated when the calculations are made. After satisfying the formation of both silicates, the remaining Al_2O_3 and H_2O will be used to form aluminum hydroxide. But by repeated trials it was found that there is always a little water left. It is quite certain that a part of the "surplus water" is to be found in the limonite. Moreover, since "loss on ignition", indicated in this paper as H_2O, includes organic matter present, which is of common occurrence in some samples, it is only natural that the determined percentage of "water" is slightly higher than the actual combined water. The results will be given in Table I.

According to the calculations thus made, it is evident that only monohydrate of alumina, shown as diaspore (or boehmite or both) in the table, could exist in the two samples, most likely in others too. This stands in a striking agreement with the microscopic observations mentioned before, which indicate that diaspore is the dominant crystalline hydroxide of aluminum. The aluminum monohydroxide constitutes about 75% of the bulk of the high grade bauxite, while in the "vermicular" ore it amounts only to some 15%.

TABLE I. MINERALOGICAL COMPOSITION CALCULATED FROM CHEMICAL ANALYSES:

Sample	Chemical composition		Mineral constituents calculated	
Fine "vermicular" bauxite from Yunwushan (N).	SiO_2	37.08	Kaolinite & halloysite	79.72
	Al_2O_3	43.95	Diaspore (or boehmite, or both)	14.64
	Fe_2O_3	0.57	Fe_2O_3	0.57
	TiO_2	2.97	TiO_2	2.97
	H_2O (loss on ignition)	14.35	H_2O left	0.93
		98.92		98.73
Fine massive bauxite from Yunwushan. (M_2).	SiO_2	8.32	Kaolinite & halloysite	17.80
	Al_2O_3	69.42	Diaspore (including boehmite, if present)	73.44
	Fe_2O_3	0.58	Fe_2O_3	0.58
	TiO_2	7.86	TiO_2	7.86
	H_2O (loss on ingition)	13.70	H_2O left	0.20
		99.88		99.88

As will be noted from the table, the amount of aluminum silicates varies greatly in the fine "vermicular" and the fine massive bauxite, being up to 80% in the former and less than 20% in the latter. This feature is also quite in accordance with that shown by thin sections already described.

IV. RELATION OF SPECIFIC GRAVITY TO THE QUALITY OF THE BAUXITE.

From a study of specific gravity of the bauxite, it is found that it shows a close relationship to the quality of the latter. The following is a list of the specific gravities of a series of samples taken from the Yunwushan section, accompanied with their respective SiO_2 and Al_2O_3 contents.

TABLE II. RELATION OF SP. GR. TO SiO_2 AND Al_2O_3 CONTENTS.

Sample[1]	47_1	N	N_1	M_1	M_2
Al_2O_3	43.28	43.95	50.20	50.00	69.42
SiO_2	41.52	37.28	32.62	32.89	8.32
Sp. gr.	2.47	2.56	2.58	2.69	2.96

According to the above table it is certain that specific gravity of the bauxite increases with its Al_2O_3 content but decreases as SiO_2 increases. Obviously,

1. For the form of these samples, please refer to Table V to be given below.

when Table I is referred to, it must also vary as the proportions of its chief mineral constituents present, *i. e.*, kaolinite and halloysite and diaspore. This could be explained by the fact that specific gravity of these three minerals differs considerably from one another as will be seen from the following list:

Halloysite........................2.1
Kaolinite........................2.61
Diaspore........................3.4

Granting that the specific gravity of the "amorphous" aluminum monohydroxide is equal to that of its crystalline form, diaspore, it is thus clear that a bauxite with more monohydroxide of aluminum would be definitely heavier than that which contains a larger amount of kaolinite and halloysite.

In order to verify the above statement, the specific gravity of two samples, N and M_2, once used for mineralogical calculation in the preceding section, has been calculated from the computed percentages of their mineral constituents (Table III). The results thus obtained are fairly satisfactory. In the operation, the specific gravity of halloysite was regarded to be equal to that of kaolinite owing to their approximate similarity in mineralogical characters and that of TiO_2 assumed to be represented by that of rutile. The presence of Fe_2O_3 has not been taken into account because of its negligible percentage. But the calculated value of the specific gravity is a little higher than that actually determined. This difference may be partly due to the fact that the porosity of the specimens has been neglected.

TABLE III. RELATION OF SP. GR. TO THE PROPORTIONS OF MAIN CONSTITUENTS OF THE BAUXITE.

Sample	Kaolinite & halloysite	Diaspore (& boehmite ?)	Sp. gr.[1]	
			A	B
N	79.72	14.64	2.77	2.56
M_2	17.80	73.44	3.30	2.96

1. A.....Sp. gr. calculated.
B.....Sp. gr. determined.

In conclusion, proportions of SiO_2 and Al_2O_3 and hence kaolinite and halloysite and aluminum monohydroxide act as the chief factor governing the variation of specific gravity of the bauxite. If sufficient data in regard to the specific gravity of the bauxite are available, some rules of estimation of its mineralogical composition by specific gravity would possibly be thence derived. At any rate, specific gravity is a safe indicator of the quality and its determination may be employed as a useful field test.

V. "VERMICULAR" STRUCTURE OF THE DEPOSITS

Among the various dominant forms of the bauxite as described before, the "vermicular" type merits special mention not only owing to its unique occurrence but also on account of its bearing on the genetic problem of the deposits. There are four outstanding features of this type to be noted. (1) The "vermicular" tubes or patches are scattered in the matrix without any distinct arrangment, but their direction of elongation seems to be often, if not always, oblique to the bedding plane. (2) Owing to the variation in nature of the bauxite, the "bauxite-profiles" of different localities, even near to one another, usually differ considerably. In spite of this, there is a common feature of most sections observed, the "vermicular" structure being mostly well-developed in the upper portion while the lower part being frequently massive and free from the tubes or

Fig. 2. Showing the tortuous form of a "vermicular" tube (60T) produced by its veining through the matrix. It is to be noted that relics of the latter set in the tube are frequently crescent-shaped, 50 ×.

patches. (3) The "vermicular" tubes are always found to diverge as tortuous veinlets into the matrix and then often contain abundant relics of the latter, which usually appear convex toward the margins, pointing to the direction to which the tubes tend to migrate (Fig. 2). (4) There is a striking contrast in chemical composition between the tubes and matrix. A tube and its adjacent matrix have been analysed separately[1] and their respective composition is giving in the following table:

TABLE IV. CHEMICAL COMPOSITION OF "VERMICULAR" TUBE AND MATRIX.

Sample	SiO_2	Al_2O_3	Fe_2O_3	H_2O
60_1T (matrix)	34.92	51.21	1.39	13.76
60_2T (tube)	44.14	41.19	1.86	14.28

It is clear from the comparative study thus made that the matrix contains more Al_2O_3 but less SiO_2 than the "vermicular" tube.

Considering these facts together, it is quite obvious that something must have been carried away into solution from the tubes. A process of leaching like this is as usual mainly ruled by the percolating water and well-developed in a certain horizon near the surface, which is often under the influence of descending meteoric waters. Thus the limitation of the vermicular tubes chiefly to the upper portion of the bauxite affords a strong indication of the existence of that process. Forms of the tubes are also suggestive of such a process, for their tortuous habit with relics of the matrix must have been produced by percolation of certain solutions through the matrix.

The most convincing evidence bearing on the problem is the chemical contrast between the two distinct parts as shown in Table IV. This difference may be due to either removal of Al_2O_3 from or addition of SiO_2 to the tubes. But judging from the absence of any sign of downward migration of SiO_2 and the local concentration of silicates rather than prevalent silicification, the second alternative seems to be impossible. On the contrary, as will be seen a moment later, many analyses show that the Al_2O_3 content of the bauxite increases with depth. It may thus be concluded that the formation of the "vermicular" tubes is due to downward leaching of Al_2O_3 from the matrix. Evidently, this is analogous to the forming of tubular cavities of some laterites, from which ferric oxide, instead of alumina, has been carried away into solution.

1. Analyses made by Mr. Y. C. Shang.

VI. DOWNWARD ENRICHMENT OF ALUMINA

In the preceding, it has been already inferred that the vermicular tubes of the bauxite must have served as paths for the migration of something leached downward, which is most probably of Al_2O_3: Such a view is well backed by field evidence, for in a section of Yunwushan the writer has observed that there is a zone of enriched Al_2O_3 near its base as shown in the following table.

TABLE V. ANALYSES OF A SERIES OF SAMPLES TAKEN FROM A SECTION OF YUNWUSHAN

Sample	Depth[1] (m)	Characteristics	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	H_2O
		Overlying coal series					
47_1	0.0	Dark brown carbonaceous bauxitic shale with plant remains & pyrite nodules.	41.52	43.28	2.79	1.53	13.87
N	1.0	Brownish yellow fine bauxite showing marked "vermicular" structure.	37.28	43.95	0.57	2.97	14.35
N_1	2.5	Light grey fine bauxite with less "vermicular tubes".	32.62	50.20	0.70	1.80	14.47
M_1	4.0	Grey fine bauxite with scattered minute "vermicular" patches.	32.89	50.00	0.85	2.36	13.86
M_2	5.5	Grey fine bauxite with a little carbonaceous material & pyrite.	8.32	69.42	0.58	7,66	13.70
M_2	6.5	Subjacent purplish ferruginous shale.	33.20	36.08	16.06	2.80	12.53
3	7.0	Basal hematite layer.	2.90		52.75(% Fe)		

From the above table it will be noted that in the upper 5.5 meters of the section SiO_2 decreases whereas Al_2O_3 increases steadily with depth, though both change gradually and vary only a little. However, as the lower part is reached,

1. Approximately estimated from the contact of the coal series with the layer of 47_1 downward.

these two constituents suddenly attain their extremities respectively, thus Al_2O_3 increasing so much as to form an ore of good quality. This clearly points to the effect of downward leaching of Al_2O_3 from the surface.

Consequently, the problem will naturally arise as to which agent is responsible for the process. According to pedogenic processes, the downward migration of sesquioxides with concurrent concentration of silicic acid at the surface is the result of leaching in an acid medium produced by percolating water solutions enriched with CO_2 and humic acids in a region covered with forest or scrub [9, p. 449 & p. 452; 11, p. 73-74.] In the present case, since the top part of the section passes upward into a coal series and itself also bears abundant carbonaceous material, the original soil moisture must have been acidic so that Al_2O_3 could be leached out from the mass and finally redeposited in the lower horizon.

By experiments, G. A. Thiel has discovered that more alumina would be leached out from its silicate compounds in the presence of bacteria and sulphates than that taken into solutions by sterile natural waters. The most active agent for the reaction, as he believes, is the sulphuric acid generated by the oxidation of freshly precipitated colloidal iron sulphide by bacterial activity [12, p. 480-483]. In view of the common occurrence of pyrite nodules in the "cap" of our section, the downward enrichment of alumina may be explained as well in the light of this theory. Perhaps, sulphuric acid and humid acid were present simultaneously and each contributed to the process of solution and removal of alumina, as is suggested by F. W. Freise [3]. It should be admitted however, that the supposition thus made is based upon the single section of Yunwushan; whether the enrichment phenomenon could be encountered elsewhere requires much careful observation in the future.

It may be pointed out here that a survey of most literature dealing with bauxite deposits will indicate that most of them show a downward enrichment. The outstanding example is the Arkansas bauxite. With this deposit, W. J. Mead is of the opinon that the downward secondary enrichment of alumina is due to the solubility of bauxite in surface solution, thus leaving the kaolin and hence the silica in a relatively higher percentage at the surface [7, p. 50]. No account of the nature of the agents for dissolving the bauxite has been given by him. Considering the overlying pyrite-bearing lignite of the bauxite, C. H. Behre Jr. suggests that sulphuric acid and various organic acids may have been instru mental in their formation [1]. Accordingly, this seems to be analogous to the case of the Kueichou bauxite under investigation.

In the discussion of the enrichment of Al_2O_3, the existence in most sections of a basal ferruginous shale and hematite layer underlying the bauxite, which is extremely poor in iron, is also worthy of consideration. Concerning this fact, a question may well be raised whether the bauxite originally contained considerable iron, which has been leached out and finally redeposited at the base—just as the case of Al_2O_3. In view of the similarity in colloidal properties between these two constituents, Al_2O_3 and Fe_2O_3, the positive side might be the truth, but owing to the complicated nature of bauxite formation the argument is never conclusive.

VII. SUMMARY.

1. This paper is mainly concerned with the quality of the Kueichou bauxite in the three areas discovered, *viz.*, Yunwushan, Wangbi and Wangkuan.

2. The bauxite layer as a basal part of the Lower or early Middle Carboniferous coal series occurs on an erosion surface of the Lower Ordovician siliceous dolomite and underlies the *Chaetetes*-bearing Huanglung Limestone.

3. The bauxite is light colored, fine and compact, occasionally showing pisolitic and oolitic structures. The upper portion of the deposits usually contains scattered greyish, translucent "vermicular" tubes and patches essentially of halloysitic composition.

4. It is mostly of low grade, usually composed of about 45% of Al_2O_3 and 35% of SiO_2. Against these, its iron content is extremely small, amounting to only 1 % or less. But the bauxite of the lower portion of a section of Yunwushan is an exception, containing about 70% of Al_2O_3 and only 8% of SiO_2. The combined water is always around 14.5%.

5. Microscopic study reveals that the bauxite is composed essentially of an "amorphous" mass, enclosing a few crystalline minerals, namely, in order of abundance, kaolinite, halloysite, diaspore, zircon, limonite, pyrite, boehmite(?), gibbsite, quartz, rutile and sphene.

6. The form of the bauxite is usually a safe indicator of its quality. The "vermicular" variety is almost always rich in SiO_2 and hence kaolinite and halloysite, whereas the bauxite of high grade found in the Yunwushan section is fine

and free from the "vermicular" tubes. The coarse massive variety shows similarity in composition to the "vermicular" one.

7. Mineralogical calculations from chemical analyses show that the "vermicular" bauxite, most probably also the coarse massive one, comprises about 80% of kaolinite and halloysite, together with 15% of aluminum monohydroxide (probably diaspore or boehmite or both), which is the only possible form of aluminum hydroxide in the bauxite under consideration. In the fine massive one which contains about 70% of Al_2O_3, the monohydroxide amounts to about 75%, but there are only 20% of kaolinite and halloysite present.

8. Specific gravity of the bauxite varies as its aluminum monohydroxide content and inversely as the amount of kaolinite and halloysite present. It is mostly around 2.5, but may attain 2.96 as the monohydroxide of aluminum increases to about 75%.

9. It is probable that the formation of the "vermicular" structure is due to downward leaching of Al_2O_3 on the ground that the tortuous tubes, often oblique to the bedding plane, are mainly confined to the upper portion of the deposits and contain outward bending relics of matrix, from which they show a marked chemical contrast, containing more SiO_2 and less Al_2O_3 than the matrix.

10. The section of Yunwushan, where the coal series is comparatively well-developed, shows downward enrichment of Al_2O_3; its main body (about 5.5 m thick) is rich in SiO_2 while the lower portion (about 1 m thick) contains a large amount of Al_2O_3. This may be ascribed to a process of downward leaching, in which both sulphuric acid and humic acid are likely instrumental.

In conclusion, the writer wishes to acknowledge his indebtedness to Dr. C. Y. Li for his kind help in the field; to Mr. Y. Hseung for valuable suggestions, especially with regard to the genesis of the bauxite; and to Mr. Y. C. Shang for undertaking some analyses that bear his name in the paper. Many thanks are also due to Drs. T. H. Yin and T. K. Huang for the sympathetic interest which they have always shown during the progress of the field work and to Dr. Y. C. Cheng for discussion of many points in the laboratory and for his kindness in reading through the manuscript. Lastly he is greatly indebted to Dr. S. S. Yoh for his hospitality and for the identification of all the fossils collected.

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Glacial Features in North-western Kuangsi*

By

T. C. SUN

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With 2 Plates.

Evidence of glaciation has been steadily accumulating in many places throughout south-western China since the discovery of moraines and ice-sculptured landforms in the Lushan area. Two years ago I was fortunate enough to have the opportunity of accompanying Prof. J. S. Lee in western Hupei, western Hunan and the north-eastern part of Kuangsi when he was engaged in making general observations of the glacial phenomena in these regions. Experience gained in that journey has enabled me to recognize certain striking phenomena in north-western Kuangsi, including Hochih[1], Nantan[2] and Tienao[3] districts. In the course of my fieldwork I did not trace them in detail. Nevertheless it will be of general interest to note the fact that this large area was also glaciated in Quaternary times.

I was first attracted by the fine, tough and whitish gray clays, subangular pebbles with doubtful striations, and low hills both on the eastern and western sides of the Hochih valley. Two different facies of the clays were recognized in the vicinity of the Hochih city. The upper part is a white-gray tenacious silty clay with angular fragments of silicious rocks, while the lower, a pure white tough clay. Between them comes in an erosional surface marked by yellowish brown contorted bands. These deposits led me to suppose that they were probably of glacial origin. Further finding of erosional features and deposits supported this view.

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* Received for publication in September 1943.

1. 河池; 2. 南丹; 3. 天峨.

GLACIAL EROSION-FEATURES

Straight valley. From Hochih to Nantan along the highway no obvious glacial features were seen, except for a few rock-basins and rolling hills. The valley from Nantan city to Chingshankou[1] (Pl. I, Fig. 1) is singularly straight, running north-south, about 200 m wide, 5 km long. It traverses the Lower Carboniferous and Permian limestones. Scratched pebbles have been found at a place 1 km north of Nantan. To the east of Chingshankou there is another valley running east-west at an elevation of about 700 m above the sea-level. It reaches some 250 m in width, 2 km in length. The Lower Permian limestone underlies the floor which is covered by a thin layer of white tough clay, and sandstones with shales form a moderate slope on the one side, while limestones stand precipitously on the other. These two valleys meet together at the Hsiaochang village[2], 5 km to the north of Nantan. The latter is dominantly U-shaped with more valleys and some amphitheatrical depressions on the northern side. Numerous angular and subangular scratched pebbles of greenish gray sandstone are scattered all over the valley-floor.

A U-shaped valley was found some 50 km west of Luchai[3]. It extends southward from Hualiang[4] village of Yuelihsiang[5] about 5 km long with a strikingly uniform width of about 700 m (Pl. II, Fig. 1). This valley runs along the strike of the Permian limestone; and striated pebbles of a sandstone of distant origin are found in it. The floor of the valley is rather flat covered with a layer of alluvium, followed in turn by a layer of grayish tenacious clay. These together with the underlying limestone are dissected by the present stream in the form of a V-shaped channel. A depression is located near the Hualiang village at the head of this valley. Further north we come to the boundary between Kuangsi and Kueichou.

At the southern end of this valley a sudden drop occurs at a point 2 km to the south of Yueli. It is cut by a fault running E-W forming a cliff. The rocks on the down-thrown side are yellowish shales and green sandstones of Triassic age.

Another U-shaped valley is developed at an elevation of 900 m above the sea level, and situated some 40 km east of the Tienao district. The valley is

1. 青山口; 2. 小廠; 3. 六寨; 4. 化良; 5. 月里鄉.

rather straight throughout its whole length with the Pochieh[1] village standing at its southern end. It runs nearly along a thrust plane, and reaches about 6 km in length 600 m in width. The Triassic shales and sandstones form the walls of the valley with some tributary valleys coming from the eastern and western sides in the lower course. Below one of the tributary valleys occurs a cross-wall which runs across the main valley. This is succeeded by a second cross-wall separated by a distance of less than 2 km. About 3 km further below stands a third cross-wall which is the highest of the three. All these cross-walls are cut at both ends. And through one of the dissected gaps runs the present stream. The other gap hangs high, forming, in fact, a wind-gap. On the upper side of each cross-wall or "riegel" the valley slightly broadens out, forming local basin with a paternoster arrangement.

This striking U-shaped valley running from north to south suddenly changes its elevation at the neighbourhood of the Pochieh village. Erratic blocks of hard sandstone up to 1 m across are scattered all over the bottom of the valley. Boulder-clay is found near the two cross-walls, one in the vicinity of the Lichung[2] village and the other, 2 km south of that village. Numerous scratched pebbles were collected in this place. One specimen of the scratched pebbles bears the striations about 1 foot in length. The same boulder-clay spreads on the valley side.

A third U-shaped valley which I met with is the Szehots'un[3] valley, about 50 km NWW of Hochih District or some 10 km SWW of Tachang[4]. This valley is located at an elevation of about 600 m above the sea level. It attains a length of some 2 km and a width of about 300 m. The valley runs straight to the NNW and SSE from the Szehots'un. It is of U-shape with a flat bottom covered by a layer of boulder-clay. Here, too, I found scratched pebbles here and there. Another valley, likewise U-shaped, approximately 400 m wide and several km long was observed at a place 7 km south-east of Natihsiang[5]. It traverses Devonian shales and Permian limestones. This valley runs nearly NS joining the Szehots'un valley at a point 1 km to the south of Laochieh[6] (Pl. II, Fig. 2). Erratics of the Triassic sandstone abound in the valley. All of them came from a range which is separated by another parallel valley from that formed by the Permian limestones. The Boulder-clay forms the hummocky hillocks in

1. 拔結; 2. 立中村; 3. 泗河村, 大廠; 5. 那地鄉; 6. 老街.

the vicinity of Fanpots'un[1]. They rise to a height of about 10 m above the bottom of the valley. The hillocks are so arranged that they appear to have been originally continuous, forming an arcuate ridge with its convex side facing the south. It runs across the valley, about 1 km further north of the Fanpo village. These are however denuded to such an extent that their continuation can hardly be traced. Hillocks of this type are most probably remains of end moraines that have suffered considerable erosion since glacial times.

The fourth U-shaped valley lies at a place some 40 km to the west of the Hochih city. It runs from Changlaohsiang[2] to Shuiluts'un[3] in a NNW direction about 7 km long and 400-500 m wide (Pl. II, Fig. 3). The Devonian limestones, shales with quartzose sandstones and Permian limestones form the high cliffs on both sides of the valley. In the middle part of this valley fine tough clays with boulders form the hummocky hillocks near the Nahua[4], Pochang[5] and Powang[6] villages. Most of them are in elongated forms having a length of about 30 m, a width of 20 m and a height of about 10 m above the valley-bottom. And they stand with the *stoss* side on the NNW and lee on the SSE. At the southern end of the valley there is an elongated hill of Devonian silicious shales about 15 m high, 40 m long and 20 m wide. It shows a similar trend as the above-mentioned hillocks with its steep slope facing the south. Most part of Changlaohsiang stands on the top of hill. Although I did not find glacial striation on the rock-surface, the general form of the hillocks together with its smooth surface suggests a *roche moutonnée*. Erratic blocks up to half a meter across and striated pebbles are not uncommon in this valley. On both sides of the valley several dry gaps hang high. Circumstantial evidence shows that such features cannot be due to tectonic or other causes. I am thus led to consider these gaps as spillways formed in glacial times.

Firn-basins. Elongated and circular depressions occur on the top of the heights which I have visited. Some of them are directly connected with the U-valley; others are more or less isolated.

About 20 km north of the Nantan city and 2 km south of Mangchangchen[7], on the top of the mountain there is a broad depression attaining a size of about 1.5 km long, 1 km wide and more than 60 m in depth. It is carved

1. 范坡村; 2. 長老鄉; 3. 水陸村; 4. 那話; 5. 坡廠; 6. 坡枉; 7. 芒場鎮.

out of the Middle Devonian limestones and shales, and lies at an elevation of about 800 m above the sea-level. The bottom of this basin is covered with a layer of brownish boulder-clay which is overlain by a layer of loam. An opening on the southern side of this basin joins a valley running NNE. Striated pebbles were found in the vicinity.

Some 30 km east of Luchaichen[1] in the neighbourhood of the Lungsa[2] village, near the boundary of Kuangsi and Kueichou, a similar basin was met with. The bottom of this broad elongated basin is also covered with a layer of yellow loam, followed downward by a layer of tenacious reddish brown clay, occasionally mixed with subangular pebbles of sandstones.

Similar broad depressions were found at several other localities: *e.g.*, one situated in the vicinity of the Pochieh[3] village about 35 km east of the Tienao city; another in the neighbourhood of Shangkaots'un[4] 2 km east of Yuli; and the third in the environs of K'ungmingts'un[5] 5 km west of Mangchang[6] at the altitude of about 900 m above the sea level.

Since the Shangkaots'un is entirely developed in the limestones it may be suspected that it is merely a doline. But the finding of scratched boulders in it proves its glacial origin.

Cirques. Along the highway from Yalinhsiang[7] to Chiapanhsiang[8] at a point about 2 km north of Chiapan there are two adjacent funnel-shaped depressions on the western flank of the mountain. They stand at the same elevation of about 900 m above the sea level, and each has a size of 120 m in diameter. Triassic shales and sandstones surround the funnel with steep walls on all sides except in the front where each of the depressions has a narrow opening peeping down to the west. About 30 m below the opening, in each case, a valley extends forward for not more than half a km. Then they become confluent running to the west. A brownish boulder-clay covers the floor, and a low smooth ridge forms a rampart across the mouth where striated pebbles were found. These two small rock-basins are divided by a sharp ridge *(arête)* of pyramidal shape looming behind and between them. These gave us an impression of slightly eroded cirques.

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1. 六寨鎮; 2. 弄撒; 3. 坡結; 4. 上高村; 5. 孔明村; 6. 芒場; 7. 牙林鄉; 8. 甲板鄉.

In the neighbourhood of Tatouts'un[1] some 5 km west of Mangchangchen there is another funnel shaped depression. It is entirely carved out of Permian limestones. And it attains a size of 100 m in diameter, and lies at an altitude of about 800 m above the sea level. A narrow outlet opens to the west. A precipitous cliff forms the backwall. Below this depression starts a valley to the west. Because of the fact that this depression occurs in limestones; I am not yet certain as to whether it may not be a doline.

Piedmont Basins. Several large rock-basins were observed. A remarkable one is located in the neighbourhood of the Tienao city several km across, with high mountains surrounding it (Pl. II, Fig. 4). This open rock-basin is developed at an elevation of 800 m above the sea level, and leads to three sub-basins. One of these is situated about 4 km to the north of Tienao, another 3 km to the west in the vicinity of Chinching[2] village; and the third about 5 km to the north-east in the neighbourhood of Szushants'un[3]. Each of the basins joins the Tienao depression with a valley running between. A low cross-wall can be traced across the valley at a place a little to the north of Huoli[4]. In the Tienao piedmont basin moraine was not found, but instead, we noticed abundant striated pebbles and large erratic blocks.

Around Natihsiang[5] some 45 km SWW of Nantan the same type of depression existed (Pl. II, Fig. 5). It also leads to several sub-basins. The Kengpots'un[6] basin lies to the north about 4 km from Natihsiang; the Yangchowts'un[7] basin in the west and the Weiwang[8] basin in the southeast. This piedmont basin is estimated at about 2 km long and more than 1.5 km wide. In it were also found erratics and scratched boulders.

MORAINE-DEPOSITS AND SCRATCHED BOULDERS

Moraine-deposits do not occur extensively in this region. But in a few places, as for example in the vicinity of Fanpots'un[9], in the U-shaped valley of Szehots'un[10], Changlaohsiang, at the mouth of Pingchiaots'un[11] and the Lamats'un[12] basins and in the straight valley of Hsiaochang[13]. These deposits as a whole are characterized by an exceedingly tenacious, brownish and unstratified clay being chaotically mixed with subangular boulders of different sizes. Above them lies a thin layer of yellow or reddish loam.

1. 大頭村; 2. 金井; 3. 四山村; 4. 夥里; 5. 那地鄉; 6. 更坡村; 7. 羊迥村; 8. 威王; 9. 范坡村; 10. 泗河村; 11. 平橋村; 12. 拉麻村; 13. 小廠.

Scratched boulders have been found at many places. Generally they consist of sandstones and hard limestones of different sizes and shapes; and are scratched in all fashions. The largest boulder reaches about 1 meter across, while the smaller ones slightly smaller than the kidney. Most of them are slightly rounded. Only a few have their edges and corners preserved. They are often polished, facetted and pitted. The striations are, as a rule, straight, but occasionally curved, and some in the form of a nail-head. Sometimes they are arranged in sets on a single face with different directions.

Fine specimens of striated pebbles and boulders occur abundantly in the Hsiaochang valley 5 km north of Nantan. They almost exclusively consist of a hard, greenish, fine-grained sandstone derived from the north-western side. Because of the difficulty of preservation, scratches on the limestone pebbles are comparatively rare. But scratched limestones do also occur, though the scratches are usually worn down. The topography of the surrounding country, the generally more or less rounded form of the pebbles and their superior hardness gave us strong evidence that these striations could not have originated from landslides or solifluxion.

Similar specimens were found from Yalinhsiang about 60 km west of Luchai, from the U-shaped valley of Szehots'un and in the neighbourhood of Pochieh.

The succession of recent deposits in this region may be represented, in general terms, by a well log sunk in the neighbourhood of Lahei[1] village. Stating in descending order they consist of:

11.	Grey arenaceous clay with small pebbles	1.0 m
10.	Recent river gravels fairly fine in grade	0.8 m
9.	Whitish grey clay with a few subangular fragments	1.0 m
8.	Greyish-white, tenacious clay with a few sandy particles	0.8 m
7.	Greyish-white tenacious clay with coarse grains of sand	0.6 m
6.	Whitish grey tough clay	0.3 m
5.	Gravels with clay	0.2 m
4.	Reddish-white tough clay	0.3 m
3.	Buff sandy clay	0.3 m
2.	Dark brown clay with gravels	0.3 m
1.	Brown clay with gravels	0.7 m

1. 拉黑.

A close examination of layers 1-5 shows that they are probably reworked boulder-clay. The overlying whitish clay is apparently of glacial origin.

In connection with the development of the U-shaped valley at Laochieh[1] it may be noticed that a terrace is well preserved on both sides of it as shown in Pl. I, Fig. 2.

This terrace is covered by a thin layer of brownish yellow loam, followed by a layer of brownish tenacious clay occasionally mixed with subangular sandstone pebbles. We have, however, failed to find in them any scratched ones. The base of the terrace is formed by the Permian limestone. It attains a width of about 25 m on both sides and a height of more than 40 m above the valley-bottom. The largest of the sandstone pebbles is about 10 cm in length and width. They are derived from the same range as are the scratched pebbles found in the bottom of this valley.

Judging from the subangular form of the pebbles of distant origin and their association with a tough clay one can hardly say that the terrace was formed by river erosion. This makes me to infer that it was probably sculptured by ice. However, I failed to find any clear evidence to show that the terrace and the valley-bottom were formed at two different stages with a long interval of erosion between them. This question needs further investigation.

From what I saw in the field there appears little difficulty in deducing the type of glaciers that existed in this region. All of them must be corrie glaciers which flowed separately from independent firn-basins along the flank of mountains. Most of the ice sculptured land-forms are situated at an elevation of 600-1,100 m above the sea level.

Finally I should express my gratitude to my teacher Prof. J. S. Lee for critically reading the manuscript.

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1. 老街.

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馬振圖 湖北五峯鶴峯宜昌宜都等縣所見之冰川現象（未刊本）

費師孟 黃山地理考察 地理學報第三卷第四期

EXPLANATION OF PLATES

Plate I.

Fig. 1. Sketch showing the Hsiaochang straight valley in which scratched boulders and tough-clay are found.

Fig. 2. A cross-section in the vicinity of Laochieh, showing the terrace and the form of the valley-bottom.

Plate II.

Fig. 1. Sketch of the Yuelihsiang U-shaped valley connected with the Hualiangts'un firn-basin.

Fig. 2. Sketch showing the connection between the Laochieh and Szehots'un U-shaped valleys.

Fig 3. Sketch of the Changlaohsiang U-shaped valley showing the elongated hummocky hillocks (h), spill-ways (s) and the *roche moutonnée* (r).

Fig. 4. Topographical sketch of the Tienao piedmont basin.

Fig. 5. Topographical sketch of the environment of the Nati piedmont basin.

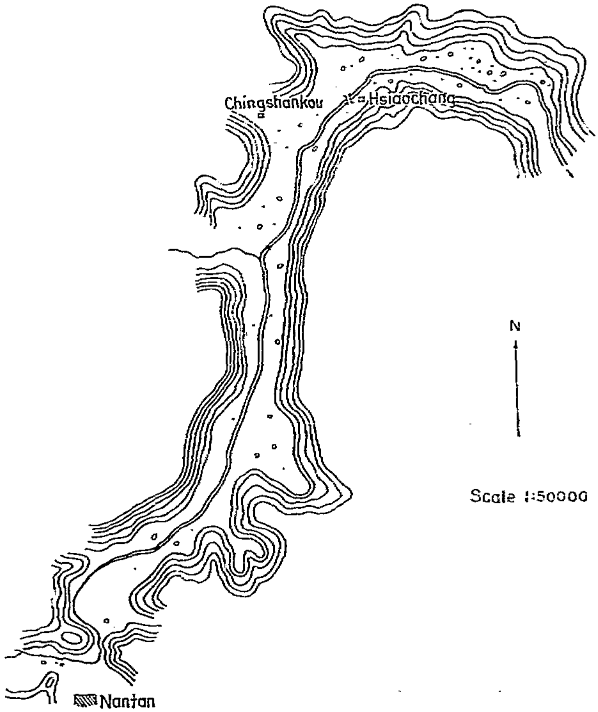


Fig. 1

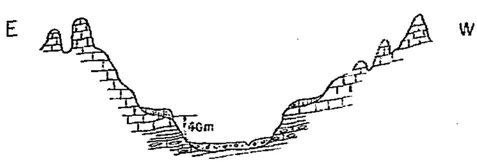
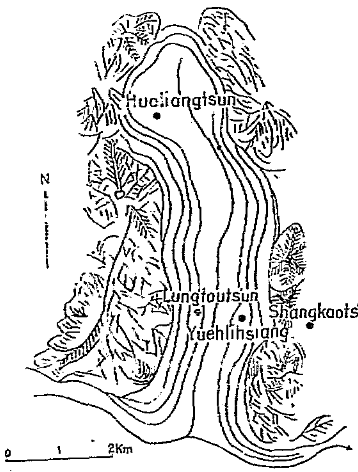


Fig. 2



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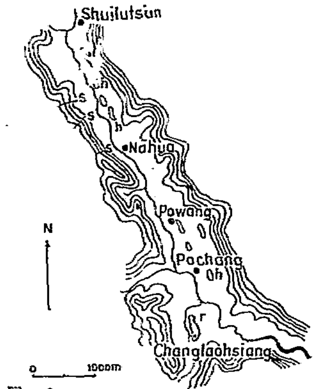

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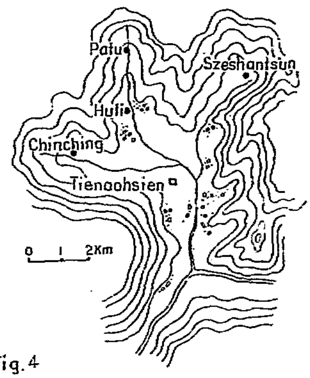

Fig. 4

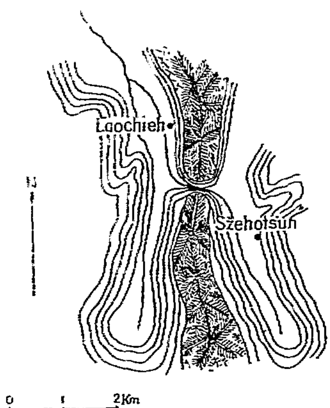

Fig. 2

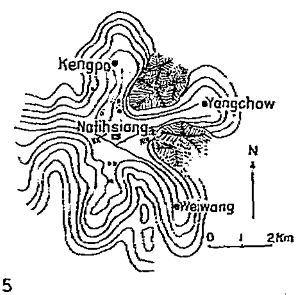

Fig. 5

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Preliminary Note on Quaternary Glaciation in Northeastern Yunnan*

By

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(*Mineral Exploration Bureau, N. R. C.*)

With 1 Plate.

INTRODUCTION

During the last five years, evidence of Quaternary glaciation has been gathered by different geologists from Hupeh, Hunan, Kuangsi, and Sikang. H. von Wissmann, in his paper on the Pleistocene Glaciation in China, has made use of the data collected by Handel-Mazzetti and Credner on the glacial phenomena of Yülungshan[1] near Lichiang[2] and Tientsangshan[3] at Tali[4] respectively; but in northeastern Yunnan, no such phenomena have yet been reported. In 1942, while travelling along the Chinshachiang[5] in a geological reconnaissance, the writers sighted some striated pebbles at the foot of a mountain called Maoerhshan,[6] Lutien[7], about 3200m above sea level. On examining these pebbles, we were led to the belief that the scratching might be due to glaciation. Since then, much attention was paid to the glaciation problem; and besides glacial deposits, a variety of glacially sculptured land-forms were also observed. In this short paper the writers wish to describe only some of the outstanding features which seem to bear out indisputably their glacial origin. A full understanding of glacial phenomena would need a more detailed and extended investigation of the region than what the writers have been able to do in their last trip.

* Received for publication in April 1944.

1, 玉龍山; 2. 麗江; 3. 點蒼山; 4. 大理 5, 金沙江; 6. 貓兒山. 7. 魯甸.

To Prof. C. Y. Hsieh, Director of the Mineral Exploration Bureau, the writers are indebted for his critical reading of the manuscript. The senior writer is grateful to Prof. J. S. Lee who led him to an initial understanding of the obscure glacial phenomena at Lushan in 1936.

GLACIAL TOPOGRAPHY

The region under study is situated between Yungshan[1] and Chiaochia[2] in the drainage area of the Chinshachiang and its main tributary, the Niulanchiang[3]; four physiographic stages have been observed. The first or the oldest stage, namely the Yoshan[4], attains an elevation of 4050 m, probably representing a monadnock in this region. Below the Yoshan, high peaks and ridges of about 3000 m form an erosional surface of the second stage. The third and the fourth stages are expressed by the old, broad valleys and the young, narrow gorges respectively. The prominent land-forms of glacial origin are restricted to the mountain-surface of the second stage, though firn depressions have been also met with at the top of the Yoshan. So far as the writers' observations go, no moraines and erratic blocks occur at an elevation lower than 2600m above sea level.

U-Shaped valleys. The valleys that first struck the writers as being impossible to be explained on the basis of stream erosion were observed at the foot of the Maoerhshan which consists wholly of Permian basalt, dipping southeastward with an angle less than 35°. To the west of the Maoerhshan, the mountain drops with a precipitous cliff to the Niulanchiang gorge; while on the eastern side, there occurs a gentle slope undulating with rolling hills, where topographical features of glacial origin are present. An excellent view of one of the U-shaped valleys can be obtained when one ascends the pass from Shansungching[5] to Tahaitzu[6] (Fig. 1.) The valley follows, with a bend, the main slope of the mountain and runs eastward. Its bottom is comparatively flat with a meagre stream running along its left side. A sudden change of the slope on both sides of the valley is often so sharp as to form a shoulder. This valley divides itself into two small ones in its lower reach where a boss of basalt standing up in between with a more or less smooth surface and a comparatively steep slope on the *stoss*-side suggests the existence of a dissected *riegel*. The

1. 永善; 2. 巧家; 3. 牛欄江; 4. 藥山; 5. 杉松箐; 6. 大海子.

two small valleys lie on a level a few meters below the main one, and a low cliff is, therefore, formed at the point of branching. The right valley follows a straight course while the left one sweeps round the basalt boss, and is dissected by a stream into a gully in its lower part. The floors of these valleys are covered by a fine clay in which small pieces of rocks and a few striated pebbles are scattered. Boulders and subangular pebbles are also found around the basalt boss. Some of them have one or two faces striated. These valleys are tributary to the north-south valley of Shansungching which too is flat-bottomed.

Another U-shaped, or in a more accurate sense, flat-bottomed valley was found about one kilometer to the south of Shansungching (Fig: 2). It runs from north to south and bends in the lower part to southwest to join the trunk valley, coming from Tahaitzu. A small stream dissects a narrow trench into the flat bottom. Low hills with hummocky contour, not exceeding 80m high, stand on both sides of the U-shaped valley. A tributary valley, with a more accentuated slope, hangs above the main U-shaped one, just at the point of bending. These phenomena can hardly be accounted for merely by stream erosion. When examined more closely, the writers found that the floor of the valley was paved with a fine and soft clay with small rock fragments. Distinctly polished or striated pebbles have, however, not been found. All the above stated valleys are developed in an altitude of 2840 m to 3037 m above sea level.

Close to the Chiaochia district where strikingly U-shaped valleys occur is situated Szushan[1], a small village standing at an elevation of about 3000 m above sea level. Here the whole mountain is composed of a weathered and fine-grained basalt. Apart from a few layers of tuffaceous shales interbedded in the upper part, the whole igneous flow is homogeneous in composition. An extended plateau marked by rolling heights and broad valleys forms the main topographical features. Near by Szushan, two U-shaped or flat-bottomed valleys trending E-W have been observed (Fig. 3). The northern one is about 3 km long, with well developed shoulders on both sides. A subcircular depression with a rather flat floor and steep wall, hangs on the north bank above the valley. It might have been a nivation cirque, if not actually a small cirque. The southern valley has a length of about one third of the northern one. They join together to form a single, broad valley in the lower part. A sluggish meander-

1. 駟山.

ing stream runs in the valley, and cuts a sharp trench into the flat bottom. The valley is filled up nearly everywhere by soft clays and muds on which grows sphagnous moss. Peat or black mud embedded with numerous plant tissues occurs in the lower valley, attaining a thickness of 1.5 m at least. Open pits have been excavated by the natives for the working of the peat. It suggests that marshes or pools for the growth of plants prevailed in the valley after the retreat of the glacier.

Apart from the localities stated above, U-shaped valleys have been also found in the environs of Sanchiachai[1] in the district of Yungshan, and lies about 25 km southwest of that city. In this region, the mountains are wholly composed of basalt, a rather resistant rock to weathering, and consequently the glacial sculpture is well preserved. The valley of Malukou[2] is again a broad and flat-bottomed one in which the floor is covered by fine clays, muds and chunks of transported rocks. At the bottom of the valley, grass and sphagnous moss are flourishing. In the middle part, a small trench is incised by a weak stream. A pyramidal hill with a rather sharp peak and a smooth face on each side, stands up to the south of the vally. It might represent a "horn" in terms of glacial topography. The whole valley is in the shape of an elongated basin with an opening towards the northwest, and joins the valley of Kanhaitzu[3]. It is, in fact, an elongated firn basin rather than a valley.

To the north of Sanchiachai, there is the Kanhaitzu valley following a nearly east-west direction and with bare rocks on both sides, representing a typical U-shaped valley. Here and there are scattered fine clays and rock fragments. Hanging to this valley are tributary valleys leading up to a gentle slope on the higher mountain. The lowest reach of these valleys near Sanchiachai lies in an altitude of more than 2750 m above sea level.

U-shaped valleys, covered by boulder-clays, are, in fact, found all over the cuesta mountain range east of the Niulanchiang and Chinshachiang. A set of less typical ones is met with in the vicinity of Yenmeti[4]. The valleys are broad and shallow but high in gradient. Hillocks composed chiefly of striated boulders and clays stand between them. They are limited to the area above the altitude of about 3000 m above sea level.

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1. 三家寨; 2. 馬路溝; 3. 乾海子; 4. 燕麥地.

In northeastern Yunnan, broad valleys of old rivers, which have not yet been affected by the headward cutting of the young streams are commonly found. But the gradient of these valleys is, as a rule, very low. For the formation of the non-graded valleys as mentioned above, glaciation seems to be the only possible explanation.

Hanging valleys. In addition to the hanging valley near Shansungching of which mention is already made, the valleys around Tahaitzu of Lutien are other examples. They are hung to the Tahaitzu depression which itself obviously formed a firn-basin. Instances of this kind have been also observed on the northern side of the Siaohaitzu[1] basin of Chiaochia but the hanging valleys are of minor size.

Cirques. During the writers' reconnaissance in northeastern Yunnan, subcircular depressions have been frequently met with on the high mountains about 3000 m above sea level. These depressions are called by the natives "Haitzu" or lake, though usually only retain little water. The problem as to how the "Haitzu" is formed, is a puzzling one. At all events they can not be excavated merely by streams. Some of these depressions are probably true cirques.

First of all, mention should be made of the depression of Tahaitzu (Fig. 4) where the writers have first discovered the cirque-like topography. The depression lies on the eastern slope of Maoerhshan and at an altitude of 3000 m above sea level. This striking basin is of an elliptical shape with its major axis of about 500 m oriented NS. The walls of the basin are rather steep, and are usually only 50 m deep except on the western side where the wall extends up to the lofty peak of the Chiaotingshan[2] with an elevation of 3200 m above sea level. U-shaped and flat-bottomed[*] valleys originating from the surrounding mountains suddenly drop into this basin. A minor stream runs down to the basin from north, and to the southeast a notch is cut through which the stream finds its only outlet. If not for this outlet, there might have been formed a great lake or "Tahaitzu" as called by the natives. Large boulders and huge chunks of rocks, sometimes a few meters across, are scattered in and around the basin. They are always associated with a fine clay. Striated pebbles have been found on the eastern side where a small U-shaped velley drops into the basin.

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1. 小海子; 2. 轎頂山.

*If these are true U-shaped valleys the occurrence of a big cirque below them is questionable. —Ed.

Along the route from Shansungching to Tanshan[1], many small corries have been observed. They all occur at the heads of the valleys which are either of a U-shape or in the form of a narrow trench due to subsequent stream cutting. One of the circular depressions is of funnel shape, with rather steep and high walls on all sides except on the east where an opening is present, through which a glacial tongue might have extended down to the U-shaped valley connected to it (Fig. 5).

Near Anchiaping[2], a small village about 15 km south of Yungshan city, a prominent cirque is carved out in the homogeneous basalt. This quaint hollow space in the mountain has a diameter estimated at its top of about 300 m and a depth of over 80 m. A single outlet runs towards the southeastern side while the other sides are surrounded by precipitous but rather smooth walls. Opposite to the outlet, stands a high peak of at least 3100 m above sea level. Along the outlet, there is only a meagre stream which runs to Anchiaping where it dissects a trench into the valley-floor. Striated pebbles were found on both sides of the valley.

Through the pass to the north of Anchiaping, the writers observed another depression of a more elongated shape, in which lies the village Tatang[3]. It is carved out in the Yangsin Limestone which forms a gentle anticline in this area. Small U-shaped valleys run into the depression from the south and the west, where peaks of smooth contour loom high.° In the southern valley, cut into the limestone, are scattered basalt boulders of about 2 m across, on the surface of which short and long striations are observable. Sub-angular pebbles are also found on the slope, in a fluviatile fan deposit, to the south of the village. This depression is, in fact, more like a firn basin than a cirque.

Turning now to the District of Chiaochia, the writers have found, at the northern foot of the Yoshan, a circular depression named Mantiensing[4] at an altitude of about 3000 m above sea level. It has a broad and flat bottom, and is bounded on all sides by steep walls of Permian basalt, except in the front where a precipitous cliff, below the depression, drops down to the deep valley of Siaoho[5], a small tributary of the Niulanchiang. As observed from a distance, it presents the form of a cirque. However, the origin of this depression is still problematic, since no close examination was made during the writers' hasty journey.

1. 炭山; 2. 安家坪; 3. 大荡; 4. 满天星; 5. 小河.

Firn-basins. Besides the large cirques described above, there are numerous minor depressions or Kars developed at the head of the valleys or near the top of mountain ranges. These are obviously the grounds favorable for the accumulation of compacted ice, by which the glaciers were essentially nourished. In fact, the whole area of the flat top of the Yoshan presents a suitable site for a huge snow-field. Even at present, there is always present a temporary snow field during the winter season. A large part of this mountain is covered with soft clay and mud on which grow sphagnous moss and some Beimu[1], a plant which usually grows in high altitude. Sub-angular basalt pebbles with one or two faces polished, some even finely striated, are scattered on both sides of a broad, shallow valley. More than a dozen of small depressions with clear water in them form marshes and pools. Judging from these and other fresh topographical features, it presents the form that the Yoshan was only recently glaciated.

Other topographic features. In addition to the above-mentioned features, small, ellipsoidal mounds of basalt are found in the eastern, gentle slope of the Maoerhshan (Fig. 6). The mounds present a smooth and hummocky contour with a steep slope facing west and a gentle one facing east or the direction along which the glaciers might have flowed. The origin of these mounds is still uncertain. In all probability, they resulted from glacial sculpturing. Other attractive features are the pyramidal peaks with steep but rather smooth slopes on all sides. They may be compared with horns of the Alps. Tzeiliangtzu[2] of Yungshan may be cited as a typical representative of these features.

GLACIAL DEPOSITS

Glacial deposits are not so well developed in the region under description. Boulder-clays of considerable thickness occur only in the lower reaches of the valleys; but so far as the writers know, they do not extend to the level below 2600 m in altitude. Since such deposits as peat and fine clays with boulders, have been mentioned in connection with the description of glacial topography, no repetition will be made here. Only two localities of notable significance are described below.

1. *Changliangtzu*[3], *Lutien*. The small village Changliangtzu is located about 3 km to the east of Shansungching where U-shaped valleys are well

1. 貝母; 2. 賊梁子 3. 長梁子,

developed. Near by Changliangtzu, there occurs a bed of boulder-clay in which basalt boulders are dominant; pieces of sandstone and a few slabs of tenacious white clay are also present. The interstices are filled by a loose matrix of reddish sandy clay. None of these materials occurs in layers or in any laminated manner. Their arrangement is entirely tumultuous.

The slabs and sub-angular boulders are obviously unassorted, with a size ranging from a few centimeters to several decimeters across. They are often rubbed and polished in one or two faces. A few are clearly marked by striations. One specimen of the striated boulders is angular in shape, with one of the faces more polished and scratched than the others. Three sets of striae can be fairly well distinguished. One set runs nearly parallel to the shorter axis of the boulder and is composed mostly of faint and fine striae. The other set, characterized by broad and shallow striae, is in the direction perpendicular to the preceding one or parallel to the longer axis of the boulder. The third set, being oblique to both, has only a few heavy striae of which two are "nail-head" in shape. These striations cannot be explained either by landslide or by solifluction, for the average grade of the region is only five per cent, as shown by a detailed survey.

2. *Lowu*[1], *Chiaochia*. Boulder-clay has also been met with in the environs of Lowu, a small country market in the foot hills on the eastern side of the Yoshan. The deposit has been incised by a mature stream lying at an elevation of 2640 m. Through the river excavation, one can distinguish the moraine into two layers. The lower layer is a fine clay, fairly well set and light gray in color; while the upper one is a tumultuous aggregate of sandy clay and basalt boulders ranging in size from a few centimeters to two meters across. The upper layer is in turn covered by loam. Some of the boulders are well polished and striated. The thickness of the moraine varies to a considerable extent. In certain places, it is over 30 m in thickness; in others only a few meters. Sometimes a veneer of this material is left on the mountain flanks as at Yiuchialiangtzu[2] in the west and Santaoyenliangtzu[3] in the east. At Yiuchialiangtzu the writers have found a cobble with two opposite faces well polished. One of these faces is marked by three parallel striae, broad and straight. With the aid of a lens, very fine striations nearly parallel to the broad ones are observable on the polished face. The cobble under consideration,

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1. 落伍; 2. 由家梁子; 3. 三道岩梁子.

is only slightly rounded at the edges and corners. It shows all the characteristics of a glacial boulder.

Besides these two localities, boulder clays are also met with at Anchiaping and Yenmeti villages on the opposite flanks of the cuesta mountain in the western part of the district of Lutien.

PROBABLE AREA AND TIME OF GLACIATION

In the region studied, it seems possible that all the mountains above the altitude of 3000 m or even some distance below have been glaciated. The mountain ranges on the eastern side of the Chinshachiang, from Chiaochia in the south to Yungshan in the north, might, for a period, have been wholly covered by snow and ice (Fig. 7). In his paper on the Cenozoic Geology of Yunnan, M. N. Bien by making use of the data collected by Y. L. Wang and C. C. Biq has suggested a probable glacial origin of the Tahailiangtzu[1] near Huiche[2] as a cirque-lake. Accepting Bien's suggestion, the glaciated area may be regarded as to have extended southward to Huiche, if not further.

The glaciated region under consideration lies just on the southeastern border of Sikang where Pleistocene Glaciation has been worked out from several mountains by Handel-Mazzetti and Ward. Consequently the glaciers in northeastern Yunnan would be the southward and eastward extensions of those in Sikang, and would naturally fall under the same period as the "Tali-Glaciation". The latter term was first proposed by Wissmann who also correlated it with the Würm Glaciation of Europe. But the difference in height is too great, as the elevation of the cirque-like depressions in northeastern Yunnan is only 3000 m while the snow line during the "Tali-Glaciation" amounted to 3900 m as indicated by Wissmann. However, considerable elevation of western China in post-glacial times may now be regarded as an indisputable fact. And it is not improbable that the further west we go towards Tibet the greater is the amount of elevation. For this reason, it is still possible to compare the glaciation under consideration with the "Tali", while keeping the possibility open that it may prove to be equivalent to the Lushan Glaciation of J. S. Lee.

1. 大海梁子; 2. 會澤.

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EXPLANATION OF PLATE I

Fig. 1. Sketch showing the U-shaped valley, west of Shansungching.

Fig. 2. Sketch showing the flat-bottom valley with a minor hanging valley, south of Shansungching, Lutien.

Fig. 3. Sketch showing the U-shaped valleys of Szushan, Chiaochia.

Fig. 4. Field-sketch showing the sub-circular depression of Tahaitzu, Lutien, viewed from east.

Fig. 5. A cirque between Shansungching and Tanshan.

Fig. 6. Small mounds with hummocky contour, at the eastern slope of Maoerhshan.

Fig. 7. Map showing the distribution of glaciers in the area between Yungshan and Chiaochia, Yunnan. Stippled area: evidence of glaciation found.

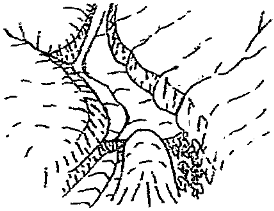

Fig. 1

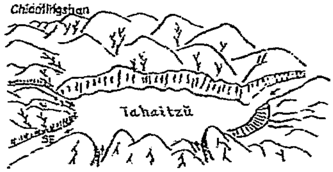

Fig. 4

Fig. 5

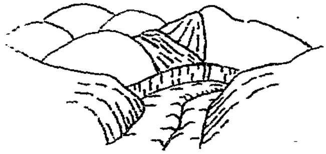

Fig. 2

Fig. 6

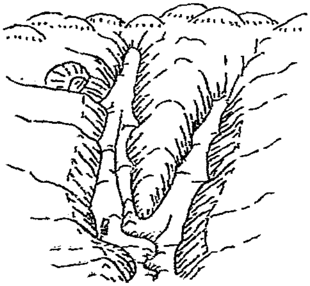

Fig. 3

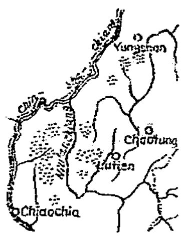

Fig. 7

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Pleistocene Morainic and Non-Morainic Deposits in the Taqlaq Area, North of Aqsu, Sinkiang*

By

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With 5 Plates.

INTRODUCTION

In April 1943, while exploring the foothills of the southern Tienshan[1] near the prosperous oasis of Aqsu-Wensu, I have repeatedly come across a series of well-preserved morainic deposits along the valley of the Terang Darya. Realizing in the field the significance of the discovery, I made some important observations on these glacial deposits and, with the aid of my colleagues, mapped the area concerned in some detail. The results are summarized in a short paper to be published in "Science Record"[2]. In the present contribution a fuller description of observed facts will be given while an attempt toward the correlation of morainic and non-morainic deposits will also be made. Owing to difficulties in printing, the contour map of the Taqlaq area on the scale of 1:40,000 is only partially reproduced here[3]. I take this occasion to tender my thanks to Dr. Y. C. Cheng and Mr. T. C. Chow for co-operation and valuable assistance in field work, and especially to Dr. C. C. Young for helpful suggestions concerning the Cenozoic geology of the Tienshan in general.

* Received for publication in April 1944.

1. For investigations in petroleum geology, a field party to Sinkiang was organized in November 1942 under the auspices of the National Resources Commission. The members of the party were C. C. Young, Y. C. Cheng, M. N. Bien, W. P. Weng, T. C. Chow and myself.

2. Huang, T. K. & Cheng, Y. C. On the Occurrence of Pleistocene glaciation along the northern margin of the Tarim Basin.

3. The originals of this map are deposited in the Library of the Geological Survey of China.

The Central Tienshan on the Sino-Soviet frontier finds its highest culmination in the Khan Tengri group (highest peak 7200m?), whose southern slope is covered with numerous snow-fields down to about 4000m. To the east, the group is separated from the Khaliqtau by the valley of the Muzart River while to the west it is continued into the Kökshal Range across the valley of the Aqsu. Between the Muzart and the Aqsu there are numerous consequent streams running roughly N-S upon the steep southern slope of the Tienshan. Each of these streams is fed by *névés* and glaciers, some of which descend into the main valleys to become true valley glaciers. The largest of such streams is the Terang Darya[1] which gave rise to the irrigation canals of the oasis of Jam[2]. The Taqlaq[3] area is situated immediately to the west of this river and forms a part of the foothill region of the main Tienshan. The village of Taqlaq (spellt Tarlak in the maps of Sir Aurel Stein) is about 2000-2100m above sea-level and is some 45Km almost due north of the city of Wensu. Geomorphologically, the country between the oasis of Aqsu-Wensu[4] and the high mountains of the southern Tienshan is characterized by five well-defined units or belts (Pl. I), which, from south to north, are: the outer gravel plains or *sais*[5], the fore-ranges, the inner gravel plains, the foothills proper, and the front ranges. The outer gravel plains are gentle-sloping desert plains covered with extensive gobi gravels and are cut into prominent terraces by the larger, permanent streams along which alluvial plains were developed and intensively cultivated. The oasis of Aqsu-Wensu with its terraces belong to this category. In fact the outer gravel plains are nothing but the marginal portion of the great plain of the Tarim Basin. The fore-ranges are called Chadan-tau (Tschadan-tau) by Futterer [3] and Gröber [4]. It is a prominent anticlinal range carved in Tertiary deposits, clearly visible from the terraces of Wensu. North of the Chadan-tau we find a narrow but continuous belt of gravelly sais, or inner gravel plains, extending from Taiterkat to Yaqach-uney for a distance of some 10 Km. Immediately north of the inner gravel plains there rise the conspicuous foothills of the Tienshan, which are 2200-3200m above sea-level and are characterized by a topography of mature dissection forming, here and there, typical badlands. These foothills are composed of red beds ranging in age from the

1. 塔蘭河; 2. 札木台; 3. 塔克拉克; 4. 阿克蘇溫宿沃野.

5. "Sai" is the Uigur name for a desert of stone or gravel, equivalent to the Chinese expression "Gobi-tan" 戈壁灘.

late Jurassic to late Cretaceous (and probably also Tertiary), while sandstones belonging to the Jurassic coal measures play also an important rôle especially along the major overthrust to the north. This latter naturally separates the foothill belt from the high front ranges of Palaeozoic schists and slates, which are found everywhere to overlie the weaker Mesozoic terrain. Being nourished by snow-fields in the very central massif of the Khan Tengri, the Terang Glacier descends quickly into the valley of the Terang Darya, which runs right across the five belts just mentioned and vanishes beyond Jam, its water being dissipated among the numerous canals and sandy fields of that big oasis. It is along the valley of the Terang that we found typical moraines at different levels. These will be described presently.

MORAINIC DEPOSITS ALONG THE TERANG DARYA

Morainic deposits are to be met with along the Terang Darya all the way from Taiterkat up to beyond Noshqey for a distance of over 35Km. Most of them occur on high terraces on both sides of the river while some are perched on plateaus or high hills. As a rule we may distinguish a higher moraine, a middle moraine and a lower moraine, which will be dealt with separately.

The higher moraines. The small plateau of Kök Depsang, occurring between the valley of Taqlaq and the valley of the Terang, rises 2300—2400m[1] above sea-level and is some 600m above the stream level of the Terang in its immediate neighbourhood. Being surrounded by precipitous cliffs of red sandstone and conglomerate, this plateau is capped by a loose, unstratified deposit of clays and boulders good outcrops of which are observable below the highest point of the plateau (point 2376 on Pl. II). There the deposit lies unconformably on steep-dipping Cretaceous sandstones with an irregular, undulating contact. It is 20-30m in thickness and appears to be roughly divisible into two parts. The lower part consists of light grey to greenish white clays, which, besides being characteristically unstratified, include numerous angular boulders of different size and origin. The larger boulders are one foot or more across and are derived from granite, schist or other metamorphic rocks of the

1. All principal elevations are determined by a transit theodolite and referred to the city of Aqsu as datum, which is 1077 m as calculated from several months' barometric readings recorded by the Meteorological Station at Aqsu.

Tienshan. In the upper part of the deposit boulders of the same nature predominate while the clay plays a less important rôle in its constitution. These boulders frequently reach gigantic size, some of the granite blocks being 4-5m across. Since granitic and metamorphic rocks are only to be found in the high front ranges many miles away, it is clear that no other agency except moving ice could have transported these "erratic" blocks for such long distances. I am inclined to consider the lower part of the deposit as boulder-clay representing the ground-moraines of an ancient glacier while the upper part is to be taken as lateral or end-moraines dropped on the ground-moraines during the melting of that glacier. On account of subsequent weathering and erosion however, much of the original morainic topography was destroyed and we see to-day, on the Kök Depsang plateau, irregularly arranged, smooth and gentle-sloping hills and hummocks representing the preserved parts of the once widespread moraine cover. The plateau is now mantled with a soft humus from which the huge granite blocks here and there emerge. When spring comes the plateau turns into a flowering verdure, hence its suggestive name Kök Depsang or green plateau. The plateau is some 2000m long and 800m broad as measured from our map.

Moraines identical to those seen on Kök Depsang are to be met with on a high hill immediately south of the latter, and therefore belong to one and the same extensive morainic deposit, having been isolated through subsequent stream erosion. Similar moraines were also found about 2Km north of Kök Depsang on a ridge, forming the southern prolongation of the Shushet-tagh. The highest morainic deposits here are 2477m above sea-level, that is, 100m higher than the highest point on Kök Depsang.

The middle moraines. Immediately below Kök Depsang morainic deposits were again met with. Being younger in age than the moraines described above, these deposits are better preserved and have a much wider distribution. Good examples of them occur near Qizil Dawan where they form long and flat-topped hills running for many kilometers along the shoulder of the main river valley, only to be interrupted by gullies cutting across them. To the east these morainic hills drop abruptly toward the bottom of the Terang valley, forming a very steep, but evenly graded, slope (except for its lower part which quickly flattens out into the talweg), usually 400-500m in height. To the west they make a similar drop for 50m or so to meet flat areas or small basins thinly covered with moraines, beyond which smaller lenticular morainic ridges here and there occur, abutting upon high rocky hills more to the west. In my opinion these flat-topped hills represent the lateral moraines of a vanished glacier and the lenticular ridges occurring to the west of them are to be considered as compound lateral moraines of the same. It is because of subsequent weathering and erosion that the original sharp and high crests of the lateral moraines were flattened out to form to-day, with a fertile humus cover, excellent grazing grounds for the herds of the few Qirghiz inhabiting the Terang valley. As can be observed near Qizil Dawan, these morainic deposits are characterized by block-moraines consisting chiefly of gigantic granite blocks, rarely of gneiss and marble, some of which reach house-size, being partly buried and partly emerging above the surface of the soil. It is important to note that these moraines are sharply separated from the moraines on Kök Depsang by steep rocky slopes, the highest points of the former being still 120-150m lower than the highest points of the latter.

Lateral moraines of similar character are continually to be observed northward from Qizil Dawan until below the Shushet-tagh. These invariably occur on a wide and flat shoulder above the steep western slope of the Terang valley. North of Shushet-tagh a western tributary of the Terang, the Noshqey Su, drops abruptly from the plateau of Noshqey, about 2400m above sea-level, into the Terang Darya 550m lower down, thus giving rise to a series of cataracts or even waterfalls along the deep canyon cut in the moraines. It is along this canyon that beautiful exposures of block-moraines as well as boulder-clays can be observed. Here the lateral moraines appear to merge into the well-stratified reddish brown loams and clays, a peculiar type of non-morainic deposit on the plateau of Noshqey to be more fully described later. Further northward, the same lateral moraines with characteristic, gigantic granite blocks, continue for many kilometers upstream when dense forests of spruce mingled with deep snow barred our way beyond which our exploration did not extend.

At Cheq Dawan about 3600m to the south of Qizil Dawan the lateral moraines described above end abruptly at a cliff in red conglomerates, which is some 100m higher than the flat areas occurring more to the south. It is in these areas that the lower moraines are found and are to be dealt with below.

Thus far we have only described moraines found on the western side of the Terang Darya. Morainic deposits however are extensively developed east of the river on high terraces and plateaus, especially on the plateau of Ara which is completely covered with thick deposits of ground moraines or boulder clay essentially at the same elevation as, and thus to be correlated with, the moraines near Qizil Dawan. Here however no distinct lateral moraines can be observed. This may perhaps be explained by the fact that the plateau of Ara once played the rôle of the meeting place for the Terang Glacier and its tributary which filled the valley of the Qichiq Terang.

The U-shaped valley. The valley of the Terang is unusually deep and its walls are abnormally steep. The grade of the walls however is rather regular, being 40% on the average. It is only toward the bottom of the valley that the walls rapidly flatten, resulting in a steep-walled and flat-bottomed valley, or in other words, a typically U-shaped valley. This latter is already clearly observable below Qizil Dawan and becomes more and more characteristic as one proceeds northwards in the more mountainous parts of the country. Morainic deposits plaster almost the whole western wall of the valley up to the level of the lateral moraines at Qizil Dawan, whilst the moraines on the eastern wall were partially eroded and gullied, leaving triangular patches between the gullies. It is probable that most of the moraines found within the U-shaped valley were laid down by the latest advance of the Terang Glacier.

The lower moraines. South of Cheq Dawan extensive morainic deposits occur on wide and flat terraces (Pl. II) which slope down immediately into the Terany Darya. These are represented by typical block-moraines forming prominent crescentic hills arranged at successive intervals. The greater, up-stream part of each of these crescentic hills is essentially parallel to the direction of the main valley and rests outwards against rocky slopes, whereas its smaller, down-stream part runs across the valley and appears convex down-stream. It is also of interest to note that each crescentic hill is separated both from the one above and the one below by a wide flat plain of ground-moraines, which rises abruptly from the River like small plateau. It seems perfectly clear that the crescentic hills are nothing but successive terminal moraines of the Terang Glacier, while the intervening plateaus would represent the "Zungenbecken" left by that glacier. From Töq Boiney to Cheq Dawan five or six terminal moraines were met with and mapped by us. Some are slender and small, others are very thick and high, the highest being the one north of Aqtash, whose crest is about 100 m higher than the plateau or Zungenbecken on the down-stream side. The freshness and the admirably well-preserved topographic features of the terminal moraines testify to their comparatively recent age; indeed these moraines are to be considered as the youngest seen by us along the Terang Darya. However young they might be, these moraines had been partially removed by the powerful Terang Darya, so that what we see to-day are only remnants of terminal moraines which once ran completely across the valley. As can be seen near Aqtash, the erratic blocks in the terminal moraines are derived exclusively from resistant igneous and metamorphic rocks of the Tienshan, with granite predominating. This latter is characterized by whitish feldspars and by the lack of dark minerals, thus giving rise to a whitish grey appearance of the rock, hence the suggestive name "Aqtash" or white stone. Some of these "white stones" are 8 or 10m across and are visible many miles away. At Töq Boiney subsequent erosion of the Terang Darya and its tributary, the Gao Gilga, is so advanced that the rock floor of red beds below the thick morainic deposits is partly exposed. Here beds of loose, perfectly waterworn gravels occur between the red beds and the moraines which always directly overlie the gravels. Smooth and facetted boulders of metamorphosed limsetone with beautifully preserved glacial striae are to be found along the ridge of Töq Boiney. Some of them were picked up by me and are now kept in the museum of the Geological Survey of China.

Moraines found on the gravel plains. Looking south from the ridge of Töq Boiney toward the hills of Taiterkat (the fore-range), one cannot fail to observe low but continuous gravel terraces on both sides of the Terang Darya which meanders across narrow alluvial plains bounded by these terraces. At a certain distance from the margin of the eastern terraces, say 500-800m, the gravel plain is dotted with numerous, small, isolated knolls or mounds arranged in a characteristic belt perfectly in alignment with the huge lateral moraine occurring to the east of Töq Boiney on the other side of the River (lower right corner of Pl. II). These mounds are sometimes of house-size and sometimes smaller, rising boldly above the general level of the gravel plain. A similar train of mounds occurs on the western terraces of the River and is likewise in alignment with the big lateral moraine found to the west of Töq Boiney. Closer observation shows that each mound consists of a single erratic block of granite, schist or marble, half-buried in gravel beds and surrounded by smaller blocks of similar origin. Thus we have two parallel trains of mounds of erratic blocks, one occurring on the eastern and the other on the western terrace of the Terang Darya. It is important to note that similar blocks, though less abundant and not forming the characteristic mounds, are to be met with in the areas bounded by the trains of mounds whereas in areas outside these latter, on the open gravel plain, not even a single erratic block has been found. Thus we cannot avoid the conclusion that the two trains of mounds represent the lateral moraines of the Terang Glacier which once descended from Töq Boiney down to Taiterkat and beyond. After the melting away of the ice stream, these moraines were rewashed and reworked by the powerful but ever swinging Terang Darya which planed down, so to speak, most of the morainic eminences to the level of the gravel plains. The huge erratic blocks, being immune to river erosion, remain in place unaffected, and this explains the development of two trains of mounds of erratic blocks.

Detailed observations were made on these partially eroded morainic deposits at Taiterkat where a prominent terrace some 10m or more above stream-level rises immediately to the west of the River. Two types of deposit form this terrace (Pl. V, Fig. 4). The lower deposit is a coarse river-laid gravel with well-assorted water-worn pebbles. The upper deposit lies disconformably on the lower and consists of unstratified, slightly consolidated, angular rock fragments and boulders of different size and origin cemented by a greyish clay matrix. It is a typical boulder-clay. From the terrace of this clay, which is evidently a terrace of erosion, there rise scattered eminences or mounds of erratic blocks identical in characters to those described above. It is clear that the boulder-clay represents the ground-moraine of the Terang Glacier while the erratic blocks are to be taken as corresponding lateral or end-moraines left by that retreating glacier. We have traced these moraines down to 2 or 3Km south of Taiterkat at an elevation around 1400m, without finding the terminal moraines of the maximum advance of the glacier. These are perhaps to be met with along the River somewhere north of Jam; if so, the glacier must have descended even considerably below 1400m. It is significant to note that these moraines laterally merge into fluviatile or fluvio-glacial deposits.

GLACIAL AND INTERGLACIAL EPOCHS

The moraines of Kök Depsang, being the highest in the Taqlaq area, were deposited before the formation of the Terang valley. They are therefore undoubtedly the oldest moraines observed. It is probable that at the time when the Terang Glacier deposited these moraines the topography as well as the drainage pattern in the Taqlaq area was quite different from the modern one. We shall call this stage of glaciation the *Kök Depsang Stage*. The middle moraines are much lower than the higher ones and are confined to the Terang valley (Pl. IV). Thus they are definitely younger than the latter and were formed at a latter stage to be called here the *Cheq Dawan Stage*. The lower moraines of Töq Boiney and Aqtash, being separated from the middle moraines by steep rocky slopes, are again younger than these latter but whether or not they are younger than the moraines below Töq Boiney and at Taiterkat is a point worth consideration. As already described above, the terminal moraines near Aqtash are wonderfully well-preserved, while the lateral moraines occurring south of Töq Boiney are so strongly eroded as to be almost beyond recognition as such. Moreover, the well-preserved lateral moraines near Töq Boiney appear to continue into the eroded lateral moraines below that point. We might assume therefore that the terminal and lateral moraines of Aqtash and Töq Boiney were formed in a halted retreating phase of the Terang Glacier which, during its maximum advance toward the Tarim Basin, laid down the lateral and ground moraines met with both north and south of Taiterkat. We propose to name this maximum advance the *Taiterkat Stage* while the retreating phase might be called the *Aqtash Substage*.

Thus we have three distinct stages of morainic deposition corresponding to three successive advances of the Terang Glacier. The earliest observed is the Kök Depsang Stage with the formation of block and ground-moraines on Kök Depsang to be called Moraines I. The second is the Cheq Dawan Stage with the formation of Moraines II. The third is the Taiterkat Stage which was immediately followed by a halted retreating phase of the glacier or the Aqtash Substage. The respective morainic deposits are to be called Moraines III and Moraines III'. Since Moraines I are around 125m above Moraines II with which they are separated by rocky cliffs, we must assume that considerable uplifting and stream down-cutting occurred subsequent to the Kök Depsang Stage. This period of down-cutting witnessed shrinkage and retreat of the Terang Glacier towards higher altitudes and may thus be called the *first interglacial*. Then the Glacier readvanced during the Cheq Dawan Stage, carrying with it Moraines II. Subsequently, uplifting and stream down-cutting again took place, while the Glacier once more retreated mountainwards. This may be called the *second interglacial*. Then again the Glacier made its third and greatest advance during the Taiterkat Stage, leaving terminal and ground-moraines or Moraines III below Taiterkat at a place less than 1400m above sea-level and only some 10Km from Jam at the northern margin of the Tarim Basin. During the retreating phase of the third advance, the Glacier halted intermittently at Aqtash, giving rise to the beautiful crescentic wreaths of terminal moraines or Moraines III' below Cheq Dawan. This Aqtash Substage was followed by further mountainward retreat of the Glacier and deposition of river gravels in the Terang valley. This already belongs to post-glacial times.

It is to be noted however that the moraines at Aqtash or Moraines III', being so much better preserved than Moraines III, might represent a full stage of glaciation or the fourth glaciation in the Terang valley. Indeed, it is quite possible that after the deposition of Moraines III the recession of the Terang Glacier did not stop at Aqtash but proceeded further mountainwards for considerable distance above that point. Then it re-advanced as far as Töq Boiney during the fourth glaciation after which it made its final recession with the formation of Morains III'. If this was true, a third interglacial period, no matter how short it might be, must have followed the Taiterkat Stage or the third glaciation. Thus we would have four glaciations separated by interglacial periods, approximately matching the four well-established glaciations in the Alps. Whether the Aqtash Stage is to be considered as an independent glaciation or as just representing a substage of the Taiterkat, can be determined only by further critical field studies.

MORAINIC DEPOSITS OUTSIDE THE TERANG VALLEY

Above Yailaq two small but permanent mountain streams, the Soraliq and the Poqlüq, become confluent to form the Taqlaq Su. Near the junction of the two streams unstratified clays with huge boulders of Tienshan rocks form high terraces. Similar boulder-clay is seen on the terrace near the school house at Yailaq. We consider these boulder-clays as ground-moraines of a glacier which once filled up the upper Taqlaq Su and thus might be called the Taqlaq Glacier. Since no morainic deposits were met with on the beautiful terraces of Taqlaq, we must assume that the Taqlaq Glacier descended only as far as Yailaq. The higher terraces on both sides of the Taqlaq Su south of Yailaq are also formed of boulder-clays, which however are more or less stratified. Moreover the surface of these terraces are not undulating as in the case of morainic deposits but flat and even, like ordinary river terraces. We consider these terrace deposits as fluvio-glacial, representing the outwash apron of the Taqlaq Glacier.

Scores of mountain streams similar to the Taqlaq Su are to be seen on the southern slope of the Khan Tengri group; some of them are comparable in dimensions to the Terang Darya. It is most likely that successive stages of morainic deposition occur in the valleys of these streams and the careful mapping of them will certainly furnish the clue to the mystery of the nature and extent of glaciations in the southern Tienshan.

NON-MORAINIC DEPOSITS IN THE TAQLAQ AREA

Quaternary non-morainic deposits forming prominent terraces are extensively developed outside the Terang valley. As a rule we may distinguish high and low terraces; the high terraces frequently develop into real plateaus whose location and arrangement have nothing to do with the present drainage system whereas the low terraces are confined to the existing river valleys. These will be described below.

The high terraces. The extensive pastures of Noshqey are underlaid by non-morainic deposits, good outcrops of which are to be seen along the miniature canyons cut into them by the Noshqey Su and its tributaries. These deposits consist of brown and reddish brown sandy loams, fine sands and, at rare occasions, gravelly beds. They are distinctly stratified and are 20m or more in thickness. Abundant shells of a small *Helix* are entombed in the loams. As stated in the preceding, these deposits merge into lateral moraines of the Cheq Dawan Stage or Moraines II, parts of which seem even to overlie them. It might be assumed therefore that the non-morainic deposits of Noshqey were laid down by the Noshqey Su at a time when the Terang Glacier occupied the main Terany valley. The Noshqey Su, being dammed up by the huge lateral moraines, might have formed a lake outside these moraines and thus the sandy loams might partly represent lake deltas. Lakes of similar origin are to be met with in the glaciated regions of the modern Karakoram. Being originally a basin, the Noshqey area became a plateau, hanging high above the deep valley of the Terang.

Deposits similar to those of Noshqey occur on the western shoulder of the Terang all the way northwards from Noshqey. They were found side by side with the lateral moraines of the Cheq Dawan Stage. It is most likely that these deposits were the products of a melt-water stream of the Terang Glacier, flowing between the hilly slopes and the lateral moraines of that glacier.

South of Taqlaq there rises the high plateau of Kök Depsang[1], some 150m higher than the terraces of Taqlaq (Pl. II). The surface of this plateau, though occasionally undulating, is, for its greater part, strikingly flat, sloping almost imperceptibly to the south in which direction it continues for about 6Km only to be interrupted by one or two gullies cutting deep below the level of the plateau. Brown loams and fine silts underlaid by coarse river gravels with water-worn pebbles, everywhere cap the plateau, reaching to 10m or more in thickness. The loams have a loessic appearance and, like the Noshqey deposits, contain shells of *Helix*. They are however distinctly stratified and cannot be considered as eolian loess. The gravels, though generally present below the loams, are sometimes wanting especially at places nearer to hilly slopes rising above the plateau. It is probable that these gravels represent the stream bed of an ancient river which flowed past Kök Depsang, southward into the open gravel plains of that time (Pl. III, Fig. 1).

Similar high terraces are to be seen in the Shkaznaq area to the west of Kök Depsang. The most prominent and the greatest of them is the terrace of Shkaznaq which is flanked by two deep valleys whose bottom is 150-200m below the surface of the terrace. Standing on a well-chosen commanding point, one can easily visualize the original plain extending all over these terraces, which then formed vast sandy or gravelly sais.

The low terraces. These are confined to the existing valleys and are typically developed along the Taqlaq Su. As a rule we may again distinguish

1. This is another Kök Depsang, some 4 Km to the southwest of the Kök Depsang already alluded to.

higher and lower terraces. The higher terraces are less extensive and are only some 10m higher than the lower ones. They are almost exclusively formed of river gravels sometimes closely associated with pseudo-talus fans. Remnants of them can be observed from Serqtash to a point where the Taqlaq Su leaves the foothill belt. Gravel terraces of similar nature also occur at the foot of the escarpment of Ainaiqliq-tagh.

The lower terraces were found along the Taqlaq Su all the way from Yailaq to its junction with the Terang Darya. They are some 15m above the stream-level and are chiefly composed of stratified river gravels, capped by a stratum of loam less than 2m in thickness. It is this loam which provides a fertile soil for the Taqlaq farmers. Indeed the low terraces of Taqlaq, irrigable by the Taqlaq Su, appear to be the only places in the whole Taqlaq area suitable for cultivation. The gravels underlying the loam, though generally well waterworn, are very coarse, sometimes reaching 1m in diameter. I consider these as re-transported moraines.

The terraces near Yaqach-uney. Below Yaqach-uney the Taqlaq Su and its western tributary, the Yürgun Qotan, meet. Above narrow strips of recent alluvial plains along the streams, there rise two prominent gravel terraces. The lower terrace is about 12m above stream-level and is to be correlated with the lower terraces at Taqlaq (Pl. III, Fig. 2: 4). The higher terrace is 30m above stream-level and is the dominant feature in the neighbourhood (Pl. III, Fig. 2: 3). Southward from Yaqach-uney this terrace slopes gently into the open gravel plain while to the west it rapidly increases in height toward the foothills where it appears to split into three terraces (Pl. III, Fig. 2: 3, 3' & 2), each being cut in gravel beds. The first terrace is clearly continued into the valley of the Taqlaq Su (Pl. III, Fig. 2: 3) and merges into the higher terraces south of Serqtash described in a preceding paragraph. The second terrace (Pl. III, Fig. 2: 3'), is slightly higher and appears to form, as it were, twin terraces with the first. However, it does not extend into the valley of the Taqlaq Su. The third or the highest terrace (Pl. III, Fig. 2: 2') is considerably higher than the lower ones and is distinctly tilted toward the south. Toward the upper Yürgun Qotan it merges into the terrace of Kök Depsang (Fig. 2: 2') with which it is therefore contemporaneous. Looming high above the third terrace south of Yürgun Qotan, there is still another terrace (Fig. 2: 1) which however is so strongly tilted and subsequently dissected that its existence becomes hardly recognizable.

The successive stages of deposition. Thus we have three distinct types of river gravels and loams in the Taqlaq area, representing three successive stages of non-morainic deposition. In the first stage the silts and loams of Noshqey were formed. This might be appropriately called the *Noshqey Stage*. To it belong the gravels and loams on the plateau of Kök Depsang and Skhaznaq. This stage of deposition was followed by extensive uplifting and stream down-cutting resulting in the formation of the Taqlaq valley in which river gravels were again deposited. This second stage of deposition might be called the *Yaqach-uney Stage* to which the terrace gravels of Yaqach-uney and those south of Serqtash belong. Subsequently, uplifting and stream down-cutting again took place and gravels and loams were laid down along the Taqlaq valley below the Yaqach-uney terraces. This is the third stage of deposition and might be termed the Taqlaq or rather Serqtash[1] Stage. Further stream down-cutting gave rise to the Taqlaq terraces and to the narrow alluvial plains along the Taqlaq Su.

CORRELATION OF MORAINIC AND NON-MORAINIC DEPOSITS

As stated in the preceding, the moraines of the Cheq Dawan Stage or Moraines II laterally merge into the fluviatile and lacustrine deposits of Noshqey. It appears evident therefore that the Cheq Dawan Stage of glaciation is contemporaneous with the Noshqey Stage of non-morainic deposition. The moraines of the Taiterkat and Aqtash Stages or Moraines III and III' are naturally to be compared with the terrace gravels found in the Taqlaq valley. But, since gravel terraces identical to and having the same height as the terraces of the Serqtash Stage occur in the Terang valley, we must consider the Serqtash Stage of deposition as definitely post-glacial. Thus the Taiterkat and Aqtash stages of glaciation are to be correlated with the Yaqach-uney Stage of non-morainic deposition.

More exact correlation of the morainic and non-morainic deposits can be established at Taiterkat where, as a result of Quaternary folding along the Chadan-tau anticline, prominent terraces were developed side by side with moraines of the Taiterkat Stage. As shown in the field sketch (Pl. III, Fig. 3), three terraces occur at Taiterkat. The lower terrace, some 10m above the level of the Terang Darya; consists of boulder clay above and river gravels below

1. Since I have coined the term "Taqlaq Series" for the red beds occurring near Taqlaq, it is better to apply the name Serqtash Stage rather than Taqlaq Stage to these gravel deposits.

(Pl. V, Fig. 4). Huge erratic blocks of granite rise high above the surface of the terrace, forming here and there isolated eminences or mounds. It is important to note that the boulder clay is laterally replaced by river gravels as we go away from the Terang valley. Evidently, this lower terrace is an erosion terrace (Pl. III, Fig. 3: 4) and is to be correlated with the terraces of the Serqtash Stage in the Taqlaq area. The boulder-clay and block-moraines (Fig. 3: 3'), being planed down by this terrace, are surely older in age than the gravels forming the Serqtash terraces, whose surface is the original surface of deposition of these gravels, and are therefore to be correlated with the older gravels of the middle terrace. This latter is less than 30m above stream level (Fig. 5: 3) and consists of river gravels with well-assorted waterworn pebbles. It is already dissected by numerous, though short and small, gullies at the mouths of which beautiful alluvial cones are developed. It would not be surprising if, in future field work, moraines are eventually found in these gravels, especially at places where the middle terrace borders the river valley. I consider this middle terrace as contemporaneous with the terrace of the Yaqach-uney Stage while the gravels forming it are to be correlated with Moraines III. The upper terrace (Fig. 3: 2) is naturally to be compared with terraces of the Noshqey Stage. It is highest along the axis of the Chadan-tau anticline but becomes lower and lower toward the north. Toward the south its surface is bent into an arc and slopes rather steeply into the gravel plain on the southern limb of the anticline. Thus we cannot avoid the conclusion that the surface of the upper terrace was folded, after the model of the Chadan-tau anticline, into a flat anticline with a steepened southern limb. That this terrace was actually folded is further shown by a thrust fault along the left bank of the Terang, which pushed folded gravel beds upon younger gravels forming this terrace. The dissection of this upper terrace is much more advanced than that shown by the middle one. Gullies are so numerous and ramifying that they cut the terrace into long, more or less parallel ridges, while huge alluvial cones, evidently deposited by temporary streams, invariably mark the mouths of those small canyons separating the ridges, coalescing to form a miniature gravel piedmont belt (Pl. III, Fig. 3: F). Above the upper terrace there occurs a still higher terrace which however is so strongly tilted and dissected that it loses its terrace character altogether and develops into a perfect dip slope upon the anticlinal range of Chadan-tau (Fig. 3: 1). This slope is composed of coarse river gravels lying unconformably on Tertiary red beds. The former dip at 10° while the latter at 30° to the north. As is shown in Pl. III, Fig. 3: 1, these tilted gravels form an anticline which is unconformably superposed upon a steeper anticline in red beds (Fig. 3: 0), resulting in what I call an anticline-in-anticline structure. It is probable that the gravels on the Chadan-tau are contemporaneous with those forming the high hills upon the terraces near Yaqach-uney; both are to be correlated with the moraines of the Kök Depsang Stage.

The geological events happened during Quaternary times at the foot of the Tienshan along the northern margin of the Tarim Basin may be summarized in the following table.

In the valley of the Terang Darya (deposits morainic)	Outside the valley of the Terang Darya (deposits non-morainic)
(A) First advance of Terang Glacier Kök Depsang Stage: Moraines I	(A) Deposition of gravels on the Chadan-tau (lower Siyü Piedmont Gravels)[1]
(A_1) First Interglacial Retreat of Terang Glacier Uplift and stream down-cutting	(A_1) Folding and tilting along the Chadan-tau
(B) Second advance of Terang Glacier Cheq Dawan Stage: Moraines II	(B) Noshqey Stage: formation of fluviatile and fluvio-glacial deposits (upper Siyü Piedmont Gravels)
(B_1) Second Interglacial Retreat of Terang Glacier Uplift and stream down-cutting	(B_1) Uplift and slight folding at Taiterkat Formation of high terraces
(C) Third and greatest advance of Terang Glacier Taiterkat Stage: Moraines III Retreat of Terang Glacier	(C) Yaqach-uney Stage: formation of fluviatile and fluvio-glacial deposits
(C') Aqtash Substage: Moraines III' Halting and further retreat of Terang Glacier	(C') ? Uplift and stream down-cutting Formation of middle terraces
(C_1) Post-glacial Formation of fluviatile deposits Uplift and stream down-cutting Formation of low terraces	(C_1) Serqtash Stage: formation of fluviatile deposits Uplift and stream down-cutting Formation of low terraces

1. Early Quaternary gravel deposits are extensively developed along both the southern and northern foothills of the Tienshan and are called by me the Siyü Piedmont Gravels (see T. K. Huang: "Report on geological investigation of some oil-fields in Sinkiang". MSS. October 1943).

THE DEPRESSION OF SNOW-LINE

Rugged peaks exceeding 4000m above sea-level occur some 12Km north-west of Taqlaq (Pl. I). They are probably formed of metamorphic rocks found just to the north of the great overthrust referred to above. Immediately below and to the southeast of a peak measuring 4475m above sea level (Pl. I, upper margin), a beautiful cirque is developed and is covered with perpetual snow which extends from the top of the peak down to the bottom of the cirque. A small or rather "embryonic" glacier occupies the bottom of the cirque and issues just a little beyond the rim of the latter. Rough determination with a transit theodolite gives the elevation of the tip of this glacier to be 3930m. As is the case with glaciers in the Alps, the lower limit of cirques from which hanging or cirque glaciers descend, approximately marks the snow-line, we might perhaps be justified in assuming 3930m as the elevation of the snow-line in the Taqlaq area. So far as I know, the snow-line on the southern slope of the Khan Tengri group has not been determined by previous observers. The snow-line of the Bogdo-Ola in the eastern Tienshan was given by Merzbacher [13] as 3652m for its northern and 3937m for its southern slope. Now, since the Tienshan is a latitudinal range and since climatic conditions are essentially the same both in the central and eastern Tienshan, the elevation of the snow-line in both regions should not be much different, and consequently it appears quite natural that my result (3930m) agrees so closely with Merzbacher's (3937m).

Many ancient cirques at present free from snow occur in the Taqlaq area. One of them, developed in Jurassic rocks, is found at the end of the Kuchi valley north of Yailaq. Its "mouth" measures 3021m above sea-level. Another occurs directly below the cirque glacier described above and was also developed in Jurassic rocks. Its "mouth" is determined at 3139m (Pl. I, upper margin). If we take the lower limit of these cirques as representing the former snow-line, this latter would be at 3021-3139m or, to give round numbers, at 3000m. Since these cirques are wonderfully preserved, it appears probable that they were the product of the latest glaciation, that is, the glaciation of the Taiterkat Stage. Thus the depression of the snow-line of the Taiterkat Stage is calculated to be 930m. Now, considerable uplifting has taken place since the deposition of the Taiterkat moraines, and, basing upon observations on old terraces, the amount of this uplift might be taken as 50m. It is therefore clear that the actual depression of the snow-line was 50m lower than we see it to-day and consequently this amount is to be added to the estimate just given. In other words, the depression of the snow-line of the Taiterkat Stage is 980m, or slightly less than 1000m. In his valuable report on "Die Gebirgsgruppe Bogdo-Ola im östlichen Tian-Schan", Merzbacher [13, p. 221] gives 1165m for the depression in central Tienshan and considers this: "ganz sicherlich als ein Minimalwert anzusehen ist. Es lässt sich aber schon jetzt sagen, dass für die grösseren Gletscher des zentralen Tian-Schan sich noch höhere Werte ergeben werden, ganz besonders grosse für jene des Südabhanges." Obrutchev [15, p. 278] is also of the opinion that the depression attains 1000-1200m. It could not be a mere accidental coincidence that my result agrees well with those of two of the most distinguished central Asiatic explorers.

DISCUSSION

Traces of former glaciation in the central Tienshan have been reported by Huntington [7], Merzbacher [11—13], Gröber [4] and many Russian investigators. According to Huntington, two major glacial epochs undoubtedly occurred in the Tienshan and in the Pamirs while the existence of five successive epochs is also held possible. It is to be noted that the differentiation of these epochs, fascinating though it may seem, is primarily based upon personal interpretation rather than by direct observation and it appears premature to establish a correlation between Huntington's epochs and our stages as clearly revealed in the Terang valley. A complete description of the observations made by Merzbacher's expeditions in the central Tienshan is, so far as I know, not yet published, but in a short account [11, p. 35] on the occurrence of moraines in the Muzart valley, he makes the following remarks:

> "Auch beim letzten Pikett Koneschar war das Haupttal (ca 2100m) durch Moränenschutt abgesperrt, welcher am rechten Ufer hoch hinauf die Bergwände einhüllt.
>
> "Das die alten Gletscher (Musart-gletscher) auch dem Gebirge hinaus in die Ebene reichten, davon geben nicht nur die Moränengeburge Kunde, welche vor dem Fusse des nach O ziehenden Gebirgesrandes liegen u. von der Expedition im folgendem Jahre auf den wege entlang des Chalyk-tau überschritten worden, sondern auch die ungeheuren Decken, Transportblöcke einschliessenden umgelagerten Glazialschuttes.. .. .. .., welche in Mächtigkeit von mehreren hundert Metern, mehr als 30 Werst hinaus in die Ebene sich heute noch erstrecken und dort teils geschlossene Plateaus bilden, teils durch Erosion in vielgestaltige, kleine Gebirgeszüge zerlegt erscheinen."

In another report [13, p. 218] he says:

> "...........so dass die von mir in einer Entfernung von ca. 50Km vom Gebirgsrande im Niveau von etwa 1250m aufgefundenen Granitblöcke vielleicht noch nicht einmal die tiefste Grenze des diluvialen Eises in jener Gegend [Musarttal] bezeichnen."

Evidently, Merzbacher found moraines at a level as low as 1250m, a level still lower than the lowest morainic deposits below Taiterkat. Since the Muzart valley is less than 50Km to the east of the Terang it is most probable that the granite blocks found by him 50Km away from the mountain border belong to Moraines III of the Taiterkat Stage. Unfortunately, previous observations including those of Merzbacher are rather fragmentary or else are confined to the northern slopes of the Tienshan so that a critical comparison between these observations and mine in the Taqlaq area is impossible. Moreover, my investigations are confined to the lower valley of the Terang Darya. It is most likely that further exploration in the upper Terang will throw more light on the history of Quaternary glaciation. According to the Taqlaq villagers, an "ice mountain" with a swallow-tailed bifurcation is to be found in the upper Terang at a point one full day's horse-riding from Taqlaq. This seems to suggest that the snout of the living Terang Glacier is some 60-70Km north of Taqlaq and that this glacier is formed by the meeting of two valley glaciers. It will be not at all surprising if more terminal moraines representing still later stages of retreat than the Aqtash Stage occur somewhere below the snout. Besides detailed mapping in the upper Terang, I suggest that explorations be carried out in all the larger valleys along the southern slope of the Khan Tengri group, especially in the valleys tributary to the Aqsu River and in the Muzart valley. I cherish the belief that a comparative study of glacial deposits and landforms around the Khan Tengri massif will furnish the key to the solution of problems of the Ice Age in the Tienshan.

Concluding, I want to point out an important fact concerning the Terang Glacier. Deploying upon the plain for a considerable distance, this glacier did not attain the expanded foot type but remained a typical valley glacier. Compared with its length, which was possibly about 100Km during its maximum advance, it was strikingly slender, its width nowhere exceeding 2Km as is shown by the lateral moraines. Thus the Terang Glacier during the Taiterkat Stage, though comparable in form and size to the Inyltcheck Glacier of the Tienshan and to the giant glaciers of the Karakoram, had peculiarities not found in any existing glaciers and appeared therefore to form a separate type, which, for lack of a better term, might be called *extended valley glaciers.* Whether the Muzart Glacier, being longer than the Terang, became an expanded foot one is a highly interesting subject for future investigators to unravel.

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EXPLANATION OF PLATES

Plate I Sketch map showing Quaternary deposits of Aqsu-Taqlaq area.

Plate II Map of Taqlaq area showing Quaternary deposits.

Plate III

Fig. 1 High terraces of Kök Densang, SW of Taqlaq, formed of horizontal gravels and silt-loam capping plateaus carved in red beds.

Fig. 2 Terraces near the mouth of the Yürgun Qotan as seen from Yaqach-uney. 1-high hill formed of river gravels which dip into the open gobi, 2-tilted terrace formed of tilted river gravels (Noshqey Stage), 2'- plateau corresponding to 2, extending to the right into the terraces of Kök Densang, 3- terrace of Yaqach-uney (Yaqach-uney Stage) extending to the right into the valley of the Taqlaq Su, 3_1 - terrace slightly higher than 3 with which it forms, as it were, twin terraces, 4- lowest terraces (Serqtash Stage), 5- stream level of Yürgun Qotan.

Fig. 3 Terraces at Taiterkat. 0- sandstones and conglomerates of the Kucha Formation (Pliocene and older) forming a rather steep asymmetrical anticline, 1- thick-bedded conglomerates forming another anticline but unconformable on 0, 2- high terraces of river gravels (Noshqey Stage) cut by ramifying gullies, 3- middle terraces of river gravels (Yaqach-uney Stage) cut by simple gullies, 4- low terraces of river gravels (Serqtash Stage) rising immediately above the Terang Darya, 3'- erosion terraces having the same height as 4, characterized by huge erratic blocks scattered on the surface of the terrace, F- torrential cones and fans.

Note: 1, 2, 3, 4 correspond to 1, 2, 3, 4 in Fig. 2 respectively.

Plate IV Successive sections across the Terang valley showing morainic deposits of different stages. Explanation for Fig. 1—Fig. 5: M1- moraines of the Kök Depsang Stage, M2- moraines of the Cheq Dawan Stage, M2, 3-moraines of the Cheq Dawan and Taiterkat Stages undifferentiated. M3- moraines of the Taiterkat Stage. M3'- moraines of the Aqtash Substage, 1- lateral moraine, 1- terminal moraine, 2- lake deposit of Noshqey laterally merging into M2, 2'- river gravels perched on a high hill near Töq Boiney (point 1862 on Pl. II), probably belonging to the Noshqey Stage, 3- terrace of river gravels (Yaqach-uney Stage), 4- post-glacial gravel terraces (Serqtash Stage).

Plate V

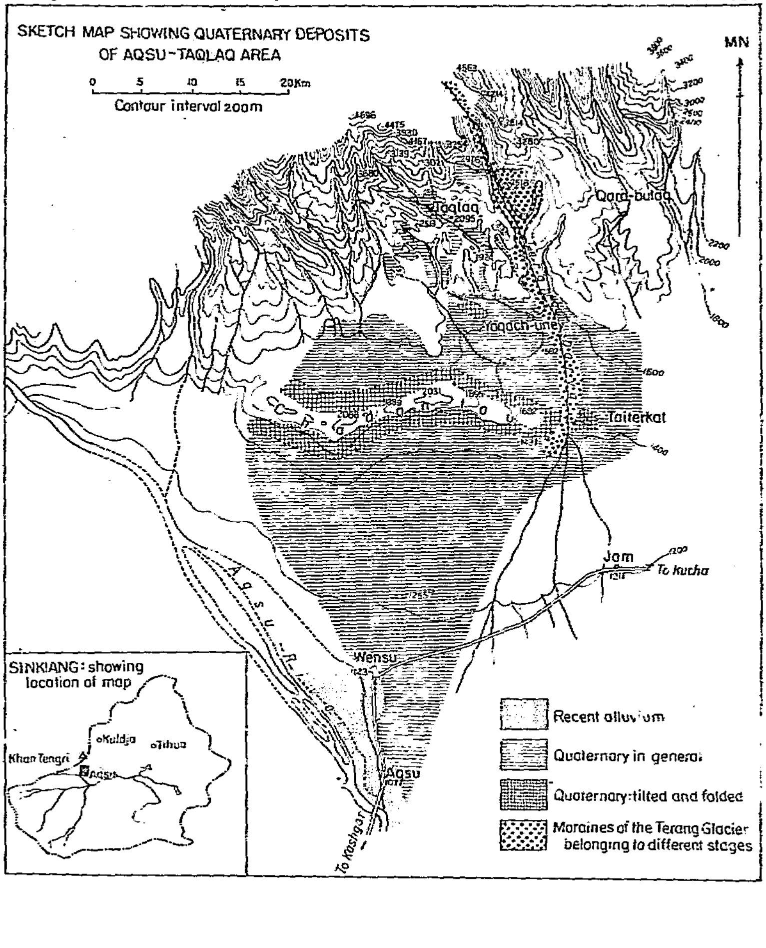
Fig. 1 Section across the Taqlaq valley. 2- terrace of river gravels and silt-loam (Noshqey Stage), 3- small hill capped by gravels (Yaqach-uney Stage), 4-terrace of river gravels (Serqtash Stage).

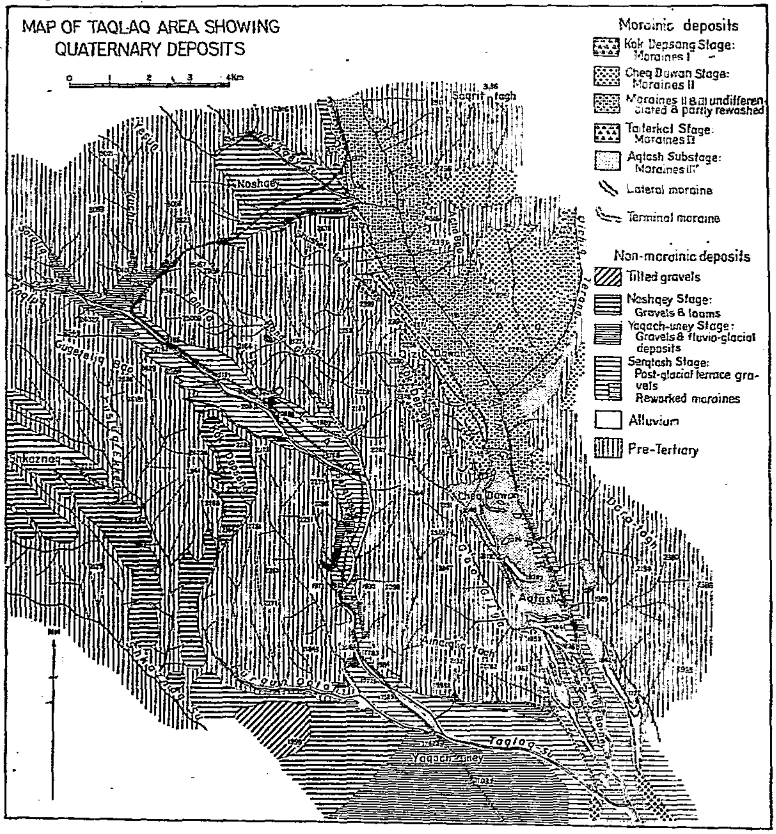
Fig. 2 2, 3, 4 same as in Fig. 1, 3,- terrace cut in gravels of 2 forming "twin terraces" with 3, 5- recent alluvium. Note that the gravels of 2 is distinctly tilted.

Fig. 3 Diagrammatic representation of terraces at Taiterkat. For explanation see Pl. III, fig. 3.

Fig. 4 Lowest terrace at Taiterkat (erosion terrace, 3' and 4 in Fig. 3). a- waterworn river gravels, b- till formed of unstratified boulder-clay, c- erratic blocks of granite and schist rising high above the erosion surface of the till.

Fig. 5 Section showing moraine of Aqtash Stage at Töq Boiney, K- Cretaceous red beds, b- ground moraine, g- basal river gravel (possibly interglacial between Moraines III and III').


SKETCH MAP SHOWING QUATERNARY DEPOSITS
OF AQSU-TAQLAQ AREA
0 5 10 15 20Km
Contour interval 200m
MN
Taqlaq
Qara-bulaq
Yogach-uney
Taiterkat
Jam
To Kucha
Wensu
Aqsu
To Kashgar
SINKIANG: showing location of map
Kuldja
Tihua
Khan Tengri
Aqsu
Recent alluvium
Quaternary in general
Quaternary: tilted and folded
Moraines of the Terang Glacier belonging to different stages


MAP OF TAQLAQ AREA SHOWING
QUATERNARY DEPOSITS
0 1 2 3 4Km
Morainic deposits
Kok Depsang Stage: Moraines I
Cheq Duwan Stage: Moraines II
Moraines II & III undifferenciated & partly rewashed
Tailerkel Stage: Moraines II
Aqtash Substage: Moraines III'
Lateral moraine
Terminal moraine
Non-morainic deposits
Tilted gravels
Noshqey Stage: Gravels & loams
Yaqach-uney Stage: Gravels & fluvio-glacial deposits
Serqtash Stage: Post-glacial terrace gravels
Reworked moraines
Alluvium
Pre-Tertiary
Noshqey
Saqrit tagh
Cheq Duwan
Aqtash
Shkoznaq
Gugerelig Bag
Yaqach-uney
Taqlaq Su

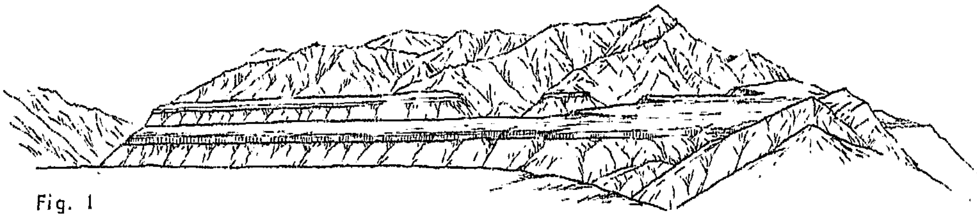


Fig. 1

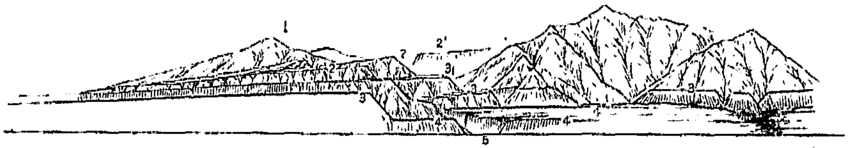


Fig. 2

Fig. 3

Huang :— Pleistocene Morainic Deposits in Sinkiang — Plate IV

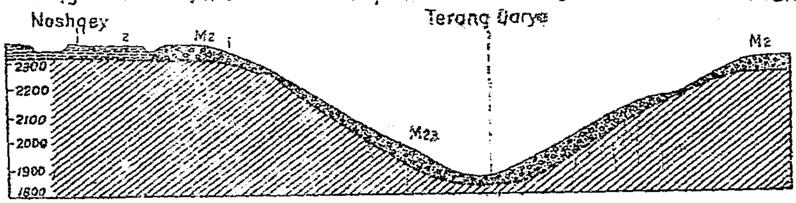


Fig. 1

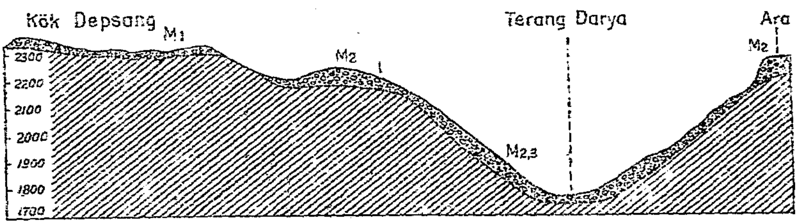


Fig. 2

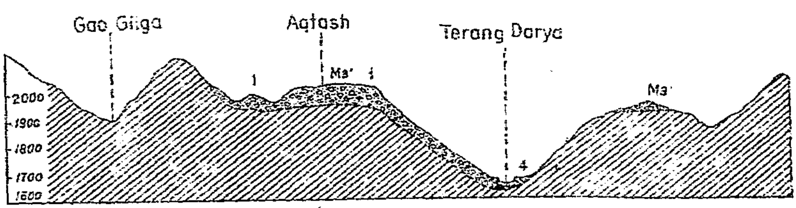


Fig. 3

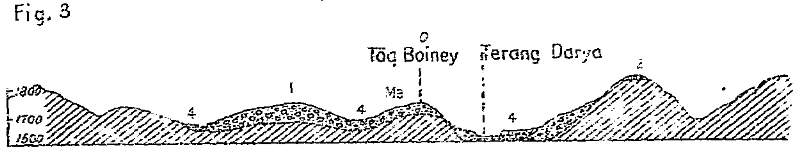


Fig. 4

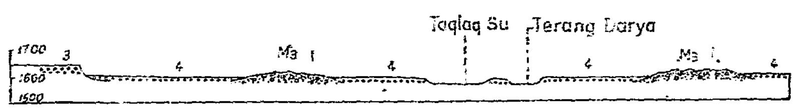


Fig. 5

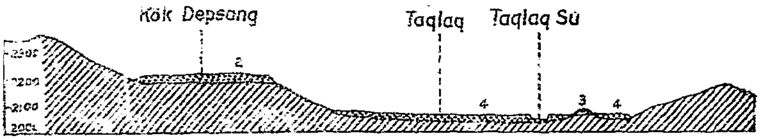


Fig. 1

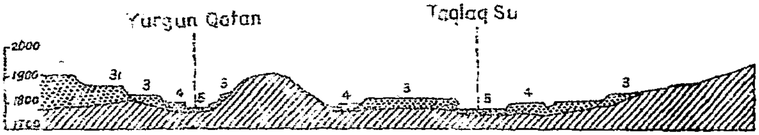


Fig. 2

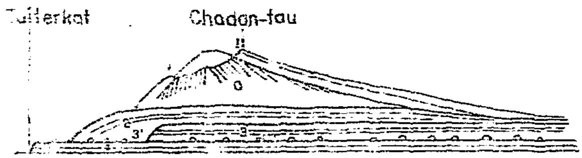


Fig. 3

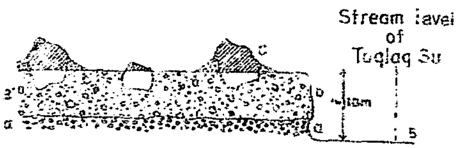


Fig. 4

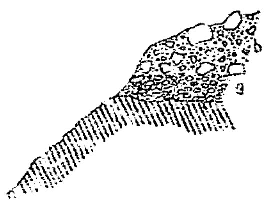


Fig. 5

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