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安徽舜耕山烟煤煉焦之試驗

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（一）緒言

實業部有設立鋼鐵廠於揚子江下游附近之計畫，其目的在開發安徽南部鐵礦，是以需煉焦煤甚殷。但我國可煉焦烟煤，大部蘊藏於北方，如山東之博山中興，河北之開灤井陘，河南之六河溝，遼寧之本溪湖等，其在南方者，除江西萍鄉外，餘如安徽之宣城涇縣，湖南之譚家山，浙江之長興，雖或爲煉焦烟煤，但究屬若何，及其儲量等等，尚須待調查試驗而後可知。中興烟煤爲國內現在煉焦煤中之最佳者，其黏性特高，揮發物約在百分三十有幾。其焦質堅硬。微孔亦多，對於冶金當甚相宜。該礦離揚子江下游不遠，又有津浦運輸之便，應當首選。其儲量豐富，而黏性特高，如此上好烟煤，在國內頗不易得，今用之單獨煉焦，滋爲可惜。苟可利用其高黏結性，與他種微有黏性烟煤參合而煉焦，倘能得可用之冶金焦炭，非特可節省中興上等煉焦煙煤，並得多利用不能煉焦煙煤，乃一舉兩得之計也。

安徽懷遠縣舜耕山，蘊藏低級煙煤甚富，其揮發物約在百分四十左右，雖其各層煤性質互有出入，總言之則其黏性極微，又無膨脹性，所成之焦，質鬆而色澤不佳，因此是煤之單獨煉焦，可謂絕無希望。但從地勢而論，并不計及其煉焦等因，該煤田應較中興爲優，蓋其與現時暫定鋼鐵廠地址爲最接近，如能用鐵道連接，由懷遠縣一直南下，其運輸之便，當爲上乘。因此之故，本所採用合煤之法，改良該煤黏性及膨脹性，以期能得可煉冶金焦而其價值又廉之煤。

合煤煉焦之法，各國沿用已久，其意義或在改良其煉焦性，或增加焦炭之硬度。（日人所經營之本溪湖煉焦廠亦應用是法製煉）凡沿用是法者，應得具高粘性之煤爲主，無粘性者爲副，或稍粘者爲主，高黏者爲副。我國烟煤約分三類，即 Bh 高碳烟炭，Bm 中碳烟炭，及 Bl 低碳烟炭是也。Bh 煤粘性固高，但膨脹性甚微，如磁縣六河溝井陘等，然亦兼有高膨脹性煤如山東博山之烟煤。Bm煤大都兩性俱兼，如中興開灤萍鄉等。Bl 煤則粘膨二性具差，舜耕山賈汪大同各煤俱屬此類，長興煤亦在 Bl 之例，但其膨性則甚高。故凡選擇粘膨兩性之煤，當集中於 Bm ，而粘性一種者則用 Bh 。用 Bl 烟煤單獨煉焦，當不合式，恐非用

合煤法不能製煉。

今舜耕山之煤已言明爲 B1 類，又其粘性微而絕無膨脹性，故擬用合煤法製煉焦炭。夃合之煤，應首選中興開灤，次及磁縣六河溝。中興於地勢論爲最合宜，開灤雖遠處北方，但可水運，亦不能稱爲不便。磁縣六河溝煤田，其路程較遠，然亦舜耕山鄰近具上好粘性烟煤之最便者。因是本試驗所以選此四煤爲混合微粘不脹之舜耕山烟煤也。

(二)試驗法

本所所用試驗煉焦方法共分三種。其一二兩種，規模甚小，其用意在辨別各混合煤之能否煉焦，及測定各煤之混合比例，其第三種爲證明一二兩種所得結果，是否有效，故其試驗較大。玆將各試驗法及其結果分述如下，以資考證，

(一)壓力試驗—小規模試驗，其種類亦繁，大都未能得要領，由尋常定揮發物時所餘剩焦炭之粘結與否而斷言之，雖用之甚夥，然往往不能得準確成績。現據各方試驗，均以烟煤之能黏結純沙或凈炭之多寡，有則用同量沙或凈炭與碎煤之團結力，以計其煉焦性。此法雖用之者衆而且久，但尙無一定試驗法，今特採用此意而暫定下列試驗方法。各種烟煤小塊經乾燥後，用磨煤器磨細，過每寸六十眼之銅篩，盛入嚴密玻璃瓶內，其合煤樣均用準確天秤配齊，裝於同樣瓶中。試驗粘性時所需之混雜物，當可用凈炭或純沙，但平地附近均不易覓得，故改用井陘焦炭，是炭廉而易得，現已備有大宗，俾每次試驗時，其性不致相差過遠。配樣時將炭磨細過篩，而祇取其在每寸四十孔篩以下在六十孔篩以上者，亦貯存於瓶內。在試驗之先，將十一克半井陘焦炭盛入三十cc乾蒸鍋，再加一克半原煤或合煤，用牛角棒和勻之，漸加五千克重量於其上，爲時準一分鐘，使煤及焦炭成塊狀。乾蒸鍋空餘處，用二十孔以下四十孔以上篩出之焦炭末盛滿之，鍋上再覆以磁蓋，然後置入電爐內，其熱度爲九百四十度至九百七十度之間，用電氣計量器測定之。十分鐘後取出，置于鐵板上冷却之，二十句鐘後，用下列方法以定其粘性強弱。其法(其儀器見附圖第一版圖一)乃將所成煤膠結塊平放於鐵板上，每塊之上下蓋一層絨布，然後將一四百克重之金屬，自六生的高壓下之。其塊之堅硬，卽該煤或合煤之粘結性，以其能耐此壓力數次甄別之。上述方法，雖試驗已久，其結果亦稱準確，但尙未能盡善，將

來或有更改之處。

（二）低溫蒸溜試驗—壓力試驗法，祇能測定煤之團結力高下，至於膨脹性焦性等，則當以蒸溜試驗鑒定之，此法已屢用於英德兩國，以測計煤之副產品。但本室之重要目的，並不在此，故其儀器裝置法（見附圖第一版圖二）雖相彷彿，而意旨則完全不同。茲將其試驗法加以說明，將七分對徑八寸長硬玻璃試管一根，在口端下邊加一長管，以容油及氣之流出。十克原煤或合煤鋪平，置於管之一邊，長約三寸。其所用電爐，為一管狀式者，將電爐燒熱至三百度時，即將貯煤管插入，漸漸增高其溫度，約每分鐘五度左右，至六百度為止。在六百度時，再蒸溜一小時，其油氣兩體亦同時流入相當玻璃器皿，並定其多寡，作為副產品記錄。所成之半焦，經冷却後，由管中取出，察其膨脹性團結性及焦之色澤與裂痕等。然後將各種半焦之性質，互相比較，以甄別其優劣。

（三）煤氣爐試驗—為證明上述兩試驗結果是否可信，當用大規模煉焦爐試驗之。但我國正式大煉焦爐，現時祇井陘煉焦廠有之，曾一度與之商借，已蒙慨諾，嗣因所費煤樣太多，及運輸與機器之不便，遂暫中止。土法煉焦需煤亦多，取費亦復不廉，，故暫用本市協和醫學校煤氣爐。此爐雖未能盡善，但其需煤少而又近在城內，試驗時大有方便之處，遂決與之商用。是爐為橫式，共分四穴，每穴可容煤約四百磅，最高熱度祇能到攝氏九百度，較之正式爐約低三百度。煉焦時每穴各置三百磅合煤末，其合煤各成分，先在本所試驗室將各原樣煤，用小碎煤機壓碎，然後稱出各成份數量，次第混合，裝入蔴布袋運至協和煤氣廠。其煤末之送入爐穴，均用人工，爐之熱度已於四日前燒起，故試驗時其最高度已達九百矣。煉焦時間為八個鐘頭，本擬延長至十二個，因其穴口封閉法不嚴密，恐空氣內侵，燃及焦炭，遂止於八小時。焦炭取出之際，即用涼水沖滅，以免燃燒。冷却後檢出一小部份，送回本所試驗室研究之。破碎試驗，為試焦法之最得用者，但本所無之，故祇可視焦炭裂痕之大小，微孔之虛密而已。其法迺將焦炭磨成一平面，其縫內孔內均摩入白粉，如此則焦黑而孔及痕俱白，一目了然，其優劣可由此判別之。

（三）煤樣說明

此次所試驗之原煤共四十種，合煤又四十種，舜耕山煤樣佔大部，該煤共分兩種，其一來自該處之大通煤礦，其二來自淮南礦務局。各處煤樣有礦廠送驗者，然大都爲本所計榮森君所採集。大通煤礦煤樣，時優時劣，係檢樣時之不一其法，抑各層煤之區別甚廣，則不得而知。淮南煤樣則不然，優劣顯因層次關係而分，且不同時採集煤樣，其區別甚少。計君所採集者，爲量最大，適值夏雨之時，全部樣煤被水淋者多次，其一部份煤末由儲煤袋中冲出，其大塊者亦不免風化，致未能實在代表該煤田煤質，甚爲可惜。中興煤有洗煤末洗煤及煤末之別，開灤樣爲特別洗煤，磁縣六河溝宜城涇縣等煤樣亦皆本所所採集者。合煤樣，首先自一份粘煤九份低粘煤起，次第混合，至一份低粘煤九份粘煤爲止。至得六七份低粘煤，三四份粘煤之數爲合式之比例。其餘合煤樣，均依照此例配合之，分析之。各樣均經過實用分析後，再加於各種試驗。茲特將各原樣煤及主要合煤樣之詳細產地，純揮發份，純固定炭，減潮樣灰份，種類記號，及試驗號分列以次，

第一表

號數	化驗室號數	產地		純揮發份	純固定炭	減潮樣灰份	加水燃率	種類記號	粘性
1	四八三	舜耕山淮南礦	西四井南一槽	四一·〇二	五八·九八	一五·六七	一·三四	Bl	微
2	四八四	仝右	南二槽	四五·七九	五四·二一	二五·六〇	一·一三	BC	微
3	五八三	仝右	南二槽	三六·九二	六三·〇八	一四·九〇	一·六二	Bl	二
4	四八五	仝右	南三槽	四二·七三	五七·二七	一三·二八	一·二七	BC	二
5	五七八	仝右	南三槽甲	四一·六〇	五八·四〇	二一·一〇	一·三四	Bl	微
6	五八一	仝右	南三槽乙	四七·六六	五二·三四	二二·九〇	一·〇四	BC	微
7	四八六	仝右	北一槽	四四·九三	五五·〇七	一〇·〇一	一·一七	BC	二

8	五七九	仝右 北一槽甲	四三·六八	五六·三二	一三·八〇	一·二四	BC	二
9	五七七	仝右 北一槽乙	四五·四三	五四·五七	一四·八〇	一·一七	BC	二
10	四八七	仝右 北三槽	四五·四九	五四·五一	九·三五	一·一四	BC	一
11	五八二	仝右 北三槽甲及丙	三八·七八	六一·二二	一四·六〇	一·五〇	Bl	一
12	五八〇	仝右 北三槽乙	四六·七六	五三·二四	一六·八〇	一·一〇	BC	二
13	四八八	仝右 北四槽	四二·八四	五七·一六	一一·九六	一·二五	BC	一
14	五八四	仝右 南二槽及北三槽統煤	三六·九八	六三·〇二	一六·三〇	一·五七	Bl	一
15	五八五	仝右 南三槽及北三槽統煤	四〇·一四	五九·八六	一七·二一	一·四一	Bl	二
16	四三三	仝右 東二井南一槽	四二·〇八	五七·九二	一一·六八	一·三三	Bl	二
17	五八六	仝右 東二井南三槽	三七·四二	六三·五八	一五·〇五	一·五六	Bl	一
18	四三二	安徽舜耕山大通煤礦統煤	四三·九一	五六·〇九	二三·三〇	一·二三	BC	無
19	五八七	仝右統煤(樣較新)	三八·七五	六一·二五	一三·四二	一·五一	Bl	三
20	三六九	山東中興洗煤	三四·二一	六五·七九	六·八二	一·九一	Bm	二十一
21	五九六	仝右煤末	三五·〇三	六四·九七	一二·三五	一·八一	Bm	十九
22	三七四	河北開灤特別洗煤	三五·九六	六四·〇四	一二·三四	一·七二	Bm	二十
23	四四七	安徽宣城大汪村	四〇·四四	五九·五六	二五·一四	一·四七	Bl	十三

24	四四九	安徽涇縣畫眉堂	三一·八五	六八·一五	一五·五四	二·一二	Bm	九
25	三一九	河北磁縣怡立公司頭煤	二二·七二	七七·二八	六·四七	三·一一	Bh	五
26	三六五	河南六河溝	二八·一五	七一·八五	一五·○七	二·四三	Bm	五
27	合 3	七十份十六號 三十份二十號	四○·二一	五九·七九	九·八三	一·四五	Bl	四
28	合 4	六十份十六號 四十份二十號	三九·四五	六○·五五	九·一六	一·五一	Bl	五
29	合 5	五十份十六號 五十份二十號	三八·五○	六一·五○	八·六四	一·五七	Bl	五
30	合 9	七十份十六號 三十份廿二號	四二·七八	五七·二二	一一·九七	一·三○	Bl	三
31	合 10	六十份十六號 四十份廿二號	四二·二一	五七·七九	一二·○五	一·三四	Bl	五
32	合 11	五十份十六號 五十份廿二號	四一·六三	五八·三七	一二·一三	一·三四	Bl	五
33	合 19	五十份十六號 五十份廿五號	三二·四六	六七·五四	一○·一○	二·○一	Bm	二
34	合 15	五十份十六號 五十份廿六號	三五·八二	六四·一八	一三·六四	一·七三	Bm	二
35	合 21	六十份一號 四十份二十號						一
36	合 22	六十份二號 四十份二十號						二
37	合 23	六十份四號 四十份二十號						五
38	合 24	六十份七號 四十份二十號						四
39	合 25	六十份十號 四十份二十號						三

40	合26	六十份 四十份	十三號 二十號						三
41	合27	四十份 五十份	十八號 二十號						二
42	合31	六十份 四十份	十九號 廿一號	三八・二三	六一・七七	一二・九一	一・五七	Bl	四
43	合37	六十份 四十份	三號 廿一號	三五・〇二	六四・九八	一二・五〇	一・七五	Bm	二
44	合35	六十份 四十份	五號 廿一號	三七・〇四	六二・九六	一七・七四	一・六二	Bl	一
45	合36	六十份 四十份	六號 廿一號	三八・九〇	六一・一〇	一四・八三	一・四八	Bl	一
46	合39	六十份 四十份	八號 廿一號	四〇・八四	五九・一六	一五・一九	一・四〇	Bl	四
47	合38	六十份 四十份	九號 廿一號	四三・四三	五六・五七	一三・二三	一・二六	BC	二
48	合41	六十份 四十份	十一號 廿一號	三七・〇四	六二・九六	一六・〇七	一・六〇	Bl	二
49	合40	六十份 四十份	十二號 廿一號	三五・三二	六四・六八	一三・二三	一・八五	Bm	四
50	合32	六十份 四十份	十七號 廿一號	三六・五五	六三・四五	一五・五二	一・六八	Bl	三

（四）研究成績及其比較

揮發物分析時所餘剩之焦或團結或否，照普通經驗，對於煤之粘結力，當可知其大概，（見附圖第二版）但因所用煤量既微，蒸溜時粘亦不免過速，（祇七分鐘）因此成績往往頗有出入，祇能察其大略耳。壓力試驗結果，雖未能十分符合，但大體不差。中興開灤粘度最高，宣城涇縣次之，磁縣六河溝又次之，舜耕山者則幾不粘，（見第一表末行粘性）由此可深信中興開灤煙煤之可以製煉冶金焦而舜耕山煤則不能煉焦。蓋煤能製焦者，其粘性當愈高愈好，舜耕山煤既缺團結性，自屬不能成焦。但煉焦之煤，其粘性應有一限度，決不能謂非具高粘性者不可。中興開灤煤爲國內所不可多得者，如捨中興開灤煤不能煉焦，則國內之煉焦

煙煤能有幾何。宜涇煤田儲量如何現尙不明，但其硫份過高，常在百份之五左右，雖其粘性亦高，對於冶金當不合宜，暫可不論。磁縣六河溝之煤可以製成焦炭爲冶金之用，所成之焦色澤硬度等均尙佳好，而其煤本身粘度則不甚高，約在「五」左右。照上述經驗，則煤之能製焦炭者，其粘性固不必十分過高，約在「五」度卽可，今舜耕山煤粘度祇在一二之間，如能參入他種高粘性煤，將其粘度提高至五度，理應可得一煉焦煤如磁縣六河溝者。是以將中興開灤煙煤及其他者逐步分配混合於舜耕山煤，製成焦塊，以壓力試其粘度。試驗結果已擇其主要者列入附表，如將其結果詳細比較，（第一表二十五至三十四號）乃知中興或開灤四十份合舜耕山東井南一槽煤六十份，可得與磁縣六河溝粘度相仿之合煤，其成份各五十份時，粘度仍舊，並不見漲。如用磁縣六河溝與之混合，雖成分增至五十份，其粘度仍如舜耕山原煤。故可斷言中興開灤之有益於合煤煉焦，而磁縣六河溝則否。

舜耕山煤層甚多，各層應有其特別性質。玆爲鑒定各層煤粘度是否相同，故將各層用四六成份混合試驗，（第一表三十至四十一號）始知各層煤粘度頗有出入，西四井之南三槽及北一槽與所試之東井南一槽相同，餘則均不如之。再各次所採之煤，粘度亦多出入，尤以大通統煤爲最甚，一則粘而一則不粘，此蓋因採集法之不同耳。大概論之，舜耕山各層固各具特別性質，而大致相似。就淮南礦區而言，西四井南三北一兩槽及東二井南一槽之煤爲上選。大通公司之煤並未將其各層次序硏究，所試驗之兩種統煤，相差太多，不敢斷言，然亦決不致無合煤之可能也。

合煤成份之比例旣可用粘度試驗法定之，以粘度之高下爲標準，然煤之膨脹性，焦性，及焦炭色澤等，均不能同時顯出，於是乃利用低溫乾蒸溜法試驗之，其主要成績，均列入第二表，

第二表

號數	半焦狀態	定揮發物時所餘剩之焦塊狀態	粘度
1	色暗黑，團結無膨性，質鬆 有不粘粉末	色暗深灰，溶結點甚少，不膨脹，	微

2	仝右惟無不粘粉末	仝右惟稍現膨性	微
4	色深灰兼有光澤，團結而不膨，質硬而緊，	色如鋼灰，溶結點稍多，稍膨，	二
7	仝右惟有裂紋	仝右	二
10	仝右惟無光澤	仝右惟無膨性	一
13	狀態與第一號同	色暗灰，溶結點少，微有膨性，	一
16	狀態與第四號同	與第三號同	二
18	黑色，幾不粘，粉末甚多，	黑色稍有粘結性	無
20	鋼灰色，甚光亮，膨脹性極強，質多孔，	銀灰色，甚光亮，塊面完全溶結，脹性極強，	廿一
22	仝右惟質更多孔	仝右惟脹性更強	廿
23	深灰色，光澤亦亮，而膨脹性亦強，	鋼灰色，光亮，塊面溶結，膨脹性強，	十三
24	深灰色，光澤高，有膨脹性	仝右	九
25	深灰色，有光澤，質硬而多孔，有脹性，	與二十號同惟膨脹性特差	五
16	仝右	與二十三號同惟脹性不及	五
29	色灰而有光澤，脹性甚強，質硬而多孔，	深灰色有光澤，溶結點多，脹性高，	五
28	與二十六號相同惟更亮	與廿九號同惟脹性不如	五

細察第二表半焦狀態，始知各煤性質完全不同，而對於膨脹性及光澤尤顯而易見，其最可注意者，即凡煤之粘度高者，

其膨脹性亦高，半焦之色澤亦亮，中興開灤粘度何以高至二十而舜耕山之煤祗有兩度者，蓋皆因膨脹性之分別故耳。至於何種物質能使其有脹性及粘性，則現時尙在試驗中，不敢斷言，大約或與煤中松香樹脂及炭輕兩質化合物有密切關係。磁縣六河溝二煤，已知其粘度不高，故其膨脹性亦遠不如中興，今舜耕山中興合煤第二十八號已知其粘度與磁縣者相仿，但尙不知其他性質，據此試驗，乃悉其他種性質均相仿，而其光澤復勝之。因此可重伸前說，第二十八號合煤即四十份中興煤六十份舜耕山煤之煉焦性當不在磁縣之下，磁縣煤既可煉焦，則合煤第二十八號之可製成冶金焦炭，亦無疑矣。（半焦狀態比較見附圖第四五六版）定揮發物時所剩之焦塊狀態（見附圖第二版）雖亦可分出優劣，但不如半焦之顯明，再粘度與炭焦狀態比較，較之與焦塊更爲吻合。又裂痕與質之鬆硬等，在半焦上均能現出，並可察其副產品之多寡，故低溫蒸溜法于此種研究似較合宜。

夫小規模試驗結果，往往與正式煉焦爐者不同，此種困難已屢見聞之矣。各國試驗煉焦均主張用正式爐試驗，然所費太鉅，不易實行，此次因各種關係，亦未能用大爐證明，前已述及矣。協和煤氣廠所產之合煤焦，經一度試驗之後，雖較小規模者易得要領，但未能確實證明此合煤焦是否適於冶金，祇知所產焦有堅鬆兩種，其最堅者爲大通統煤（42號），最鬆者爲西四井南三槽乙種煤（45號）及北三槽甲乙丙三種（48及49號）。其堅鬆固未能與粘度同高下，然大致尙不差。（焦見附圖第七版）將煤磨成平面再摩入白粉後，焦中細孔顯現，其結構情形與井陘之剖面亦不過如此，惟發見小黑點甚多，鑲嵌於焦內，（見附圖第八版圖二）乃檢出分析之，始知其爲高灰份物約百分之四十。大通統煤所成之焦，小黑點較少，（見附圖第八版圖一）因此其焦堅硬，因此推想高灰份物之與焦，或有妨礙，亦難言也。

（五）結論

中興開灤磁縣六河溝四處煤皆可煉焦，就中以中興爲最著名，據翁氏分類法，前兩者應列 Bm，次二者 Bh。Bh Bm 之分別固在其揮發物之多寡，或可以其膨脹性區別之。（恐祇限於煉焦煤而已）脹性高者爲 Bm，其較低者爲 Bh，此外之 Bl，大半僅稍粘而已，於煉焦不宜。但將中興磁縣混入於舜耕山（Bl）煤中，則 Bl 煤粘性可得增加。在 Bm（中興或開灤）四十

份Bl（舜耕山）六十份時，其合煤粘性可與Bh（磁縣或六河溝）幾相等。推原其故，蓋因Bm煉焦煤中之脹性特高耳。脹性特高於煉焦固有益，但亦不必如此之膨脹，否則磁縣六河溝煤不可製焦炭矣。Bh之本身可以製焦，其無補於合煤，乃因其脹性之不足耳。是以Bm之特脹性，非獨可以本身製焦，並可補他煤粘脹兩性之不足者，如Bl類。Bh煤祇能單獨煉焦，對於合煤毫無補益，此中與開灤之所以可貴也。

舜耕山煤各層優劣固不相同，其粘性亦復不一律，其原因則不得而知。計君所取者，知爲渠親自採集者，當最可靠，惜爲雨水淋洗，致不能代表淮南礦務局各井各層煤樣。各礦所送驗者亦不差，惟不知其採集法如何耳。最奇者爲大通統煤，其先後煤樣性質之差，出乎意外。淮南各層煤粘性之不同，或由灰份所致，蓋據分析所得，灰份之高者粘度則低，而反是者則稍高。如此論可證實，則洗煤機之設備，當有補益於舜耕山各煤之粘性也。

吾國可煉焦之煤，其加水燃率大都在一·六至三·六之間，其最低度似不能在一·六以下。今舜耕山烟煤之加水燃率皆不出一·四，理當不可煉焦，如其合煤在一·六以上當有煉焦希望，但此不可概論之。苟其燃率在一·六以上，而又兼有粘性在五六度之間者，大約俱有煉焦希望，否則恐難製焦。

大規模試驗，爲證明此研究實爲不可少者，然舜耕山處於津浦路，而井陘煉焦廠則遠在石家莊，又非平漢路不能達，苟欲實地試驗，其數量約不在二十噸以下，運輸上當感受困難，（此次運二噸淮南煤至北平時，共計十餘日之久，致各煤遍受雨淋，亦是此故。）况井陘煉焦廠，又無碎煤機器，而淮南煤大約均爲大塊，用人工打碎，恐又須慮費時日，（此次軋煤，乃用本所備有之小碎煤器，費事費時不少，欲將二十噸之多在本所試驗室內軋碎，勢所不能，）如不軋碎，用大塊煉焦，理所不許。况此次乃爲合煤試驗，不軋碎則不能混合，不混合則不克將各成份參勻，其結果較之小規模者當更不可靠。但煤質複雜，勢不可完全倚賴小規模試驗，爲確實證據也。

工業上試驗，往往由小而中，由中至大，今中小兩試驗俾可暫告結束，所待者乃正式煉焦試驗，甚盼早日得有相當方便，使

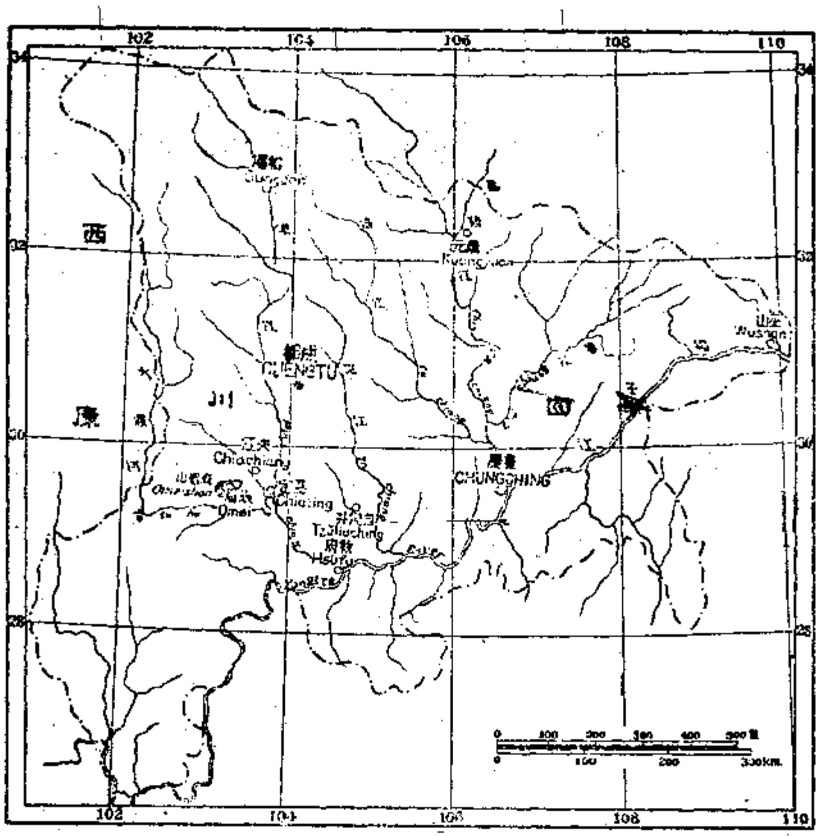
之成功，本篇之結論克以更爲證明也。

四川峨眉山地質

譚錫疇
李春昱

(一)引言

民國十八年秋，錫疇等奉命赴四川西康各處調查地質。工作一年後，於十九年冬初，由四川西部及西康返至成都。本擬轉赴西北松潘茂縣一帶，乃以時屆冬令，天寒雪積，將不便勘察，遂變更計畫，改往川南。爰於十一月二十日離成都，乘木舟順岷江而下，行三日抵樂山縣，(舊稱嘉定)，再沿雅河之北岸西北行六十里至夾江，折向西南，又四十里而達峨眉縣，縣城西南即峨眉山所在也。



第一圖　四川簡圖以示所調查峨眉山區域之位置

位置　峨眉山爲中國佛門所稱四名山之一，位於成都之西南約三百里，當北緯二九度三十分，東經一〇三度二十分，其山頂之高度，就測量所得，高出海面三〇四七公尺，高出縣城二五七二公尺。而縣城之高度，則就氣壓計沸點溫度表所得之平均數目，爲四七五公尺也。(第一圖)

前人之地質觀察　峨眉山不僅爲佛子頂禮之地，且以其山勢高聳，風景秀麗，更可資爲遊棲之所，每屆盛夏，避暑旅居者尤多，而對此名山有科學上之觀察者，則寥寥無幾。三十年前曾有美人威爾森 E. H. Wilson 來作植物學之研究，最近中國植物學者，亦嘗考察採集，然其地質情形，直至十七年夏，本所已故技師

趙亞曾，始作初次之踏勘。趙君登山，歷時僅五日，而於地層系統，均已大體清晰，作者此次調查，尚多依據。厥後兩月，有瑞士地質學者漢謨 A. Heim 奉兩廣地質調查所及中山大學之命，入川考查，亦曾涖此，其觀察偏重於地質構造，而地層則多依據趙君所作。此外日本東京地學協學會曾派人來華，廣遊數省，其所出支那地學調查報告，及地形地質圖幅，對於峨眉山亦均略有論列，但地形地質率多錯訛，不足參考。成都華西大學教授傅思特 C. L. Foster 亦有片段之地質報告，惜乏系統觀察，且所採化石，未經詳定，不免誤認。故對峨眉山地質有較清晰之研究者，只趙君與漢謨二人而已。然尤以其爲時匆忽，疏略之處，自亦難免，作者此次調查所得，亦未詳盡，問題尚多，不過彙集事實，整理成篇，以與趙漢二君所作，合貢參考耳。

作圖　峨眉山雖以名勝秀麗著稱，然向未詳測地形圖。趙君來時，曾作路線草圖，但無等高綫，不能表示地形。故作者此次攜帶儀器多件，以備測量，計有經緯儀一架，短波無線電收音機一付，用以測經度與緯度，平板一具，測高儀一只，以測地形。氣壓計及沸點溫度表等，以測高度。惜居城兩日，晝夜陰翳，經緯度未能測量，而由縣城南門至峨眉山頂，則製成五萬分之一地形圖一幅，沿路各點，均用直覘法 (Stadia method)，兩旁各點，則用交角法 (Triangulation method)

(二)沿途觀察

由縣城至伏虎寺　出南門西南行，約七里，抵保寧寺，現築馬路一段，邱陵低緩，道途平坦。路基築於礫石層上，礫石大部爲石英岩，表面光圓，小者盈寸，大者尺餘，以黃色及橙黃色黏土相膠著，結合不緊，厚度不甚明晰，然與夾江峨眉間之礫石層相較，約達三十公尺。過保寧而西，紅色砂岩與黏土，時現道旁，略向西北傾斜。經兩河口遵山麓再向西行，登一平臺，上爲報國寺，寺前低邸，爲紅色砂岩與黏土所組成，傾角五十八度，傾向西北，而寺後之小山，則爲紫紅色及綠灰色砂岩與黏土，向西傾斜，約七十度。按作者向所區分，前者屬於紅色層之中部，謂之嘉定層，後者歸於下部，名爲自流井層，此處以倒轉摺曲之故，地層傾斜西向，而愈西愈古也。

由報國寺沿溪西行，逾里許，抵伏虎寺，廟宇宏大、爲各寺冠，四山環抱，綠林蔽天，誠夏日納凉之佳處。沿路露頭，率爲

紫紅色砂岩與黏土，傾向南偏西七十五度，傾角五十五度，下爲自流井層下部之砂岩，多呈綠灰色及深灰色，富含雲母薄片，再下卽侏羅紀香溪煤系也。

在報國寺與伏虎寺之中途，有山徑西北行，可達善覺寺，沿路所見，爲自流井層紫色灰色砂岩，下有香溪系之灰色砂岩與黑色頁岩，向西偏南傾斜，傾角五十五度至七十四度。寺後有山，曰鳳凰坪，高達九八〇公尺，其上岩石，均爲白灰色質脆灰岩，層或薄或厚，向東傾斜，因近於背斜層之頂，傾角六十七度，愈西愈小，至慧燈寺，幾近水平，覆於較古岩層之上。在此灰岩之上部，曾採有瓣鰓類及腹足類化石。就化石及岩石性質與層位關係，以與他處相較，應屬於上三疊紀，而與重慶北嘉陵江下游之灰岩層相當，故亦以嘉陵江灰岩名之。

伏虎寺至新開寺　伏虎寺西香溪系之砂岩與頁岩，露頭頗廣，向西傾斜約四十至六十度，但以風化甚烈，叢林密佈，岩石層序，未能詳加觀察，僅由零星露頭，及坡上岩屑，知爲灰色砂岩與黑色頁岩相間而生。顧附近並無煤礦，或由傾斜太大，不易開採，或因煤層太薄，不利經營。而以所含化石及地層層位，與他處相較，則爲香溪煤系無疑。在伏虎寺所採植物化石，經潘鍾祥君鑑定爲

Equisetites cf sarreni Zeiller

Phyllotheca sp.

Podozamites schenki Heer

Podozamites lanceolatus (Lind. et Hutt.)

Neocalamites hoerensis (Schimper)

Cladophlebis cf kamenkensis Thomas

稍西行位於香溪煤系之下者，爲灰色灰岩夾黃灰色頁岩與灰質頁岩，仍向西傾斜，傾角約六十度至八十度，其下部尚夾紫色

頁岩一層，全體厚度，約達四百四十公尺，北與鳳凰坪上之灰岩相連，故亦屬於嘉陵江層。

雷音寺坡下有木橋，曰解脫橋，由此南行八九里，可達新開寺，寺築於高一千五百公尺之山上，爲旅川外人避暑之所。在解脫橋南不遠，卽見嘉陵江灰岩下有飛仙關層之紫色砂岩與頁岩，向西偏南傾斜，傾角六十至七十度，雖無化石可據，而地層亦能確定。飛仙關層之下，爲火山岩流，就岩石性質視之，當爲玄武岩，色深綠或深灰，質頗細，有時含白色細長之斜長石斑晶，其杏仁狀空體，常爲方解石及石英所填充，並略有磁性，有時含斑銅礦細粒，厚度約百餘公尺，但常風化成碎塊，散布山坡，故其露頭，頗不易見。山之上坡，位於玄武岩流之下者，爲深灰色及藍灰色灰岩，常帶瀝青臭味，厚約四百公尺，地層傾斜，頗不一致，時向西北，時向西南，傾角爲五十五度至八十八度，其近下部者多夾灰黑色鬆質頁岩，於此黑色頁岩及鄰近灰岩中，曾採化石多件，經黃汲清君鑑定，爲下列各種。

Cryptospirifer omeishanensis Huang

Cryptospirifer striatus Huang

Cryptospirifer semiplicatus Huang

在距底約二百公尺之上，於較純灰岩中，更採得化石數種，經黃君鑑定爲

Martiniopsis omeishanensis Huang

Athyris subtriangularis (Reed)

Schizophoria sp.

再向上部於岩流下不遠之灰色灰岩中，亦得化石二種，

Wentzelella timorica (Gerth)

Neoschwagerina sp.

按所含化石，此處灰岩，應屬於二疊紀中部之陽新層。黃君近更分陽新層為上下二部，下部為棲霞灰岩，上部為茅口灰岩，而上述之下二層化石，即相當於棲霞層，上層化石，則相當於茅口之一部也。（當作圖時，尚未如此區分而統以棲霞灰岩稱之）。

自新開寺歸來，繞道於西，在雷打坡附近，見有黃灰色頁岩及薄層砂岩，位於棲霞灰岩之下，質較鬆軟，厚約百餘公尺，其中產有三葉蟲化石，經孫雲鑄君鑑定，應屬於奧陶紀。

Taihungshania shui Sun

Acidaspis tani Sun sp. nov.

Illaenus omeishanensis Sun sp. nov.

Illaenus sp.

A Pelecypod shell (imperfect)

由雷打坡沿溪而下，復於黃灰色砂岩頁岩之上，遇棲霞灰岩，沿途暴露，約佔七百餘公尺，成西北東南走向，微向北斜，幾近直立，因溪流冲刷，常成狹谷瀑布，故名高洞口。在灰岩下部，採得Michelinia microstoma Yabe et Hayasaka在灰岩上部採得Martiniopsis omeishanensis Huang再東行出灰岩，復遇玄武岩流，及飛仙關之紫色砂岩頁岩，至解脫橋而重入嘉陵江灰岩區內。

雷音寺至清音閣　由雷音寺西行，沿途露頭，皆飛仙關層之紫色砂岩與頁岩，向東南傾斜，傾角漸行漸小，及至純陽殿，其上復覆以嘉陵灰岩，此灰岩卽鳳凰坪上之向西延長者。比至慧燈寺，則此平鋪灰岩，剝蝕以去，其下之紫色砂岩與頁岩，復露出地表，廣佈於大峨寺中峯寺及龍昇崗一帶。及抵廣福寺與清音閣附近，露出之岩石，皆為飛仙關層下之玄武岩流，其性質與色澤與在新開寺所見者無大差異，惟風化較輕，略現向東北傾斜之狀，傾角約三十度至七十度。清音閣下，常見玄武岩流，有大裂縫，如小峽谷，水從中流，因建二橋於其上，名之曰雙飛橋。一水來自石筍溝，一水來自洪椿坪，會於橋下，合流而東。

清音閣至九老洞　由清音閣西北行，可達萬年寺，其向西南行者有二路，一達大坪寺，一通洪椿坪。作者先赴大坪寺，沿清

晉閣後之山坡進行，約三百公尺，在玄武岩流下，見棲霞層之厚層灰岩，分布寬廣，直達牛心寺之西。然後繼以黃灰色之砂岩，與在雷打坡所見者相同，當亦屬於奧陶紀。稍西不遠，卽見此頁岩與薄層砂岩直與一種白灰色灰岩相接觸，此種灰岩，顏色較白，質硬且脆，廻異於棲霞灰岩，趙君另名之爲洪椿坪灰岩，謂與楊子江三峽之燈影灰岩相當，而亦歸之於震旦紀。牛心寺與會佛寺之間，有花崗岩侵入體，露頭不大。會佛寺之上卽大坪寺，二寺皆建於震旦紀灰岩之上，前者高度爲一二一〇公尺，後者爲一四〇〇公尺。

由清晉閣至洪椿坪，乃沿溪而行，三百公尺以內，皆玄武岩流。再進卽其下之棲霞灰岩，成西北東南走向，向東北傾斜六十餘度，厚度約三百餘公尺。在其下部採得化石數枚，腕腹足類及頭足類，惜以保存不佳，不克鑑定。灰岩之中，亦偶含燧石，但不甚多。此處灰岩，常成小峽谷，有黑龍江者，兩壁直立，相距不過丈餘，而高逾百尺，亦奇觀也。出峽而西，山坡寬緩，有奧陶紀之黃灰頁岩與砂岩，惟以叢林密佈，露頭甚鮮，僅有黃灰色石英岩，尚可辨識，與雷打坡牛心寺所見當相連續，奧陶紀岩層之存在，似無問題。

稍西南行，則見震旦紀灰岩與奧陶紀地層直相接觸，其間爲一正斷層，東北降落，而爲俯側。而漢謨則視爲大背斜層之一翼，無此斷層，謂奧陶紀下之寒武紀地層曾見於他處而不露出於此者，乃係受花崗岩侵衝之影響。然詳細觀察，實非如是。因花崗岩僅侵衝於震旦紀灰岩內，而未嘗涉及其他地層，寒武紀地層未暴露於此者，實受斷層之影響而沉沒耳。震旦紀灰岩，分布甚廣，發育於洪椿坪一帶，趙君以洪椿坪層名之。地層走向，大致爲西北東南，在寺東傾向東北，傾角二三十度，在寺西則傾向西南，傾角一二十度，其間成一略相對稱之大背斜層，背斜軸位於洪椿坪之西約一里許。在背斜軸附近之溝中，震旦灰岩內，尋得花崗岩露頭，岩石晶粒粗巨，長石多呈淡紅色。僅就標本觀之，與牛心寺及黑龍江南溝中所見之花崗岩，似不相同。但花崗岩與震旦紀灰岩接觸之面，未曾露出，而灰岩一部，已經變質，是否又受花崗岩之影響，未能判別。故二者接觸之關係，迄今不敢臆斷。但漢謨謂此處爲背斜層之中部，花崗岩卽震旦紀前之岩石。更謂花崗岩上現有侵蝕面，而花崗岩中含有岩壁，截止於灰岩之下

，當先於灰岩而生。此說如確，自當屬於震旦紀前。惟作者至此，遍索不得，尙未置信，欲明眞像，不能不再作考察也。

再向前進，山勢甚陡，攀登至九老洞，高出海面一千八百公尺，廟宇築於峭壁之下，其上岩石，屬於較新之地層，而其下則皆洪椿坪灰岩。就各地高度，及地層傾斜計之，則洪椿坪灰岩，下自溝中之花崗岩起，上至九老洞之峭壁止，厚度約爲八百公尺左右。

九老洞至大乘寺　九老洞以上之地層，形成絕壁，而暴露於九老洞遇仙寺之間者，爲深灰色及紫灰色砂岩及砂質頁岩，常作建築及舖路之用，厚度爲二百三十公尺，直覆於震旦紀灰岩之上。接觸之面，甚爲清晰，可於九老洞至遇仙寺之中途道旁見之，灰岩面上，似現侵蝕之跡。且以岩石性質驟異，足徵在洪椿坪灰岩生成之後，沉積間斷，灰岩暴露，曾受剝蝕。故作者擬以此部歸入寒武紀內，仍以九老洞層名之，趙君曾假定爲震旦紀之一部也。

沿崖西北行三里許抵遇仙寺，高出海面一七八〇公尺。寺下即見於九老洞砂岩頁岩之上，繼以黃灰色砂岩頁岩綠灰色灰質頁岩頁狀灰岩及餅狀灰岩等，約厚一百四十五公尺，向西北傾斜，傾角十度至十七度。以其發育於寺之周圍，故趙君謂之爲遇仙寺層。在寺西北約距底三十五至五十公尺之處，曾於深灰色灰質頁岩內，採得三葉蟲及腕足類化石甚多，經孫雲鑄君鑑定，爲下列各種，

Redlichia nobilis Walcott

Pytchoparia ligea Walcott

Omeishania yühsienssuensis Sun (gen. & sp. nov.)

Aluta sp.

Obollela sp.

趙君在此，亦曾採得化石，當時謂之爲下寒武紀，相當於楊子江三峽之石牌頁岩。由遇仙寺至蓮花石，沿途露頭皆屬此層，

惟於一二較高峯上，冠以較新之地層耳。蓮花石南，於遇仙寺頂部之黃灰頁岩中，亦採得化石數枚，由孫君鑑定爲：

Ptychoparia szechuanensis Sun sp. nov.

再南行登鑽天坡，至洗象池，高度爲二一一〇公尺。鑽天坡高約二百公尺，坡上岩石，大抵匿於密林之下，只有數處露出，可以藉知此層岩石，大約爲灰色灰岩灰質頁岩竹葉狀灰岩及白灰色灰岩，厚度約二百二十公尺，向西偏南傾斜，傾角十三度至十七度，未曾採得化石，趙君稱之爲洗象池層之下部，而作者則以代表全部洗象池層也。

由洗象池至大乘寺，約距三里，沿途露頭數處，略可辨識岩石爲灰綠色頁岩頁狀砂岩灰色石英砂岩及棕色紫色綠色砂岩頁岩等，厚約一百六十公尺。此處雖未發現化石，但砂岩頁岩露於雷打坡，而與之同屬一層者，則含有奧陶紀之三葉蟲化石，已如上述。（第一七頁）而趙君則以之併入於洗象池層，統歸於上寒武紀。漢謨更謂之爲志留紀，其言曰：

「按予之初步觀察，古生代下部地層，可分爲二部：

一，下部 ……

二，上部 以八十公尺至一百公尺之灰色板岩及泥灰岩爲特徵，顯然可別之爲上部，傅思特曾於其中採得單枝筆化石，故可推知此層似應爲志留紀，而適與三峽之龍馬頁岩相當。」

但傅思特所採化石，究屬何種，尙屬疑問。且作者已於此層採得奧陶紀化石，故既不能歸之於寒武紀，亦不能歸之於志留紀，而應爲奧陶紀，當無問題，茲爲便於敍述起見，另名之曰大乘寺層。

大乘寺至接引殿 大乘寺西南，有一百五十公尺之陡坡，曰閻王坡，坡上略成一廣袤平臺，高約二四五〇公尺，微向西北傾斜，而東南則陡落數千尺，形成絕壁。平臺之上，建有三寺，北爲白雲寺，中爲雷洞坪，南爲接引殿，相距各約二里許。自大乘寺而上，至接引殿，岩石露頭，皆爲深灰色厚層灰岩，有時夾黑灰頁岩，以錘擊之，放發青臭味。地層略向西北傾斜，傾角十度至二十度左右，與地面坡度，略相一致。在灰岩之下部，大乘寺附近，趙君曾採得下列化石：

Tetrapora nankingensis Yoh

Stylidophyllum gnomeiense Huang

Polythecalis cf. yangtzeensis Hnang

Wentzelella szechuanensis Hnang

作者亦在此採得化石數枚。

其上部露出於雷洞坪及接引殿附近者，因雪蔽覆，未克詳察，惟於荒徑砌石之磨擦面上，常見腹足類化石，略可辨其輪廓。此處灰岩．完全與新開寺灰岩相當，自亦屬於二叠紀中部之棲霞層，惟厚度較前稍減耳。

接引殿之上　以前多日．盡在彤雲密霧之中，進行工作，殊感不便。接引殿高出海面二五三九公尺，已在白雲之上，由此而上，天朗氣清，且灌木叢林，較前減少，故工作亦較便利。接引殿後，再登高坡，曰七里坡，坡頂高海面約二千八百公尺。沿坡露頭，皆深綠灰色玄武岩流。岩石表面，時現白色細長斜長石晶體，及杏仁狀小孔，填以青黑綠色之方解石與石英。磁性頗強，若以指南儀試之，可引指針轉動十度，當作者在坡上測量時，由平板上向接引殿回視，(Back Sight) 竟與原向相差至五六度之多。岩石磁性之大，當由於所含礦物富有鐵質之故也。

七里坡之上，有寺曰太子坪。由此東南行，緩坡而登，約二里有奇，經永慶寺祖師殿沉香塔天門石七天橋及普賢塔等處，而達極頂，頂上有寺曰金頂，背臨絕壁，高數千尺，就測量所得，高出海面三〇三五公尺。沿途露頭，盡屬玄武岩流，傾斜西北，與坡面略相一致，厚度較新開寺玄武岩爲大，就圖估計，約有三百五十公尺。

峨眉山頂　山頂四望，白雲無垠。東向則一無所見，惟有白雲似海，深懸崖際，波湧蕩漾，遍遮塵世。西向則見坡面緩傾，漸沒雲底，舉首遠望，雲海中島嶼棋佈，率皆南北成列，白雪巔覆，最高者卽西康之大雪山脈也。中有一峯，位於打箭爐九龍之間，據漢譔等測量所得，爲七五〇〇公尺，蓋中國之第一高山也。

金頂之南，尚有二峯，凸於崖邊，爲千佛頂，高度稍遜於金頂，萬佛頂，高度過之，測量所得爲三〇四七公尺。山頂各處，皆爲玄武岩流，在金頂及萬佛頂附近，微呈紅色，因受養化變質所致也。

金頂歸來返至萬年寺　由山頂遵原路下行，過蓮花石，乃另由新徑赴華巖頂。華巖頂爲一小峯，高一九五〇公尺，上覆以灰色灰岩，屬於洗象池層。由此沿嶺脊西北行，在灰色灰岩之下，有灰色頁岩與砂岩，就岩石性質，及其分佈觀察，應屬於遇仙寺層。再下行至初殿，則遇仙寺層之頁岩砂岩直與洪椿坪層之灰岩相接觸，九老洞層，完全缺如。考其原因，九老洞層因斷層而下落，致遇仙寺層，直與洪椿坪層相接。斷層爲西北東南方向，斷層面傾斜東北。由初殿而下，經長老坪息心所至觀心頂，所有露頭，皆震旦紀灰岩，其近於初殿者，傾向西南，傾角十六度，而長老坪以下者，傾向東北或正東，傾角二十度至三十度，中間當爲一背斜層，背軸卽位於初殿長老坪之間，向東南延長，與洪椿坪西之背斜軸，聯而爲一。

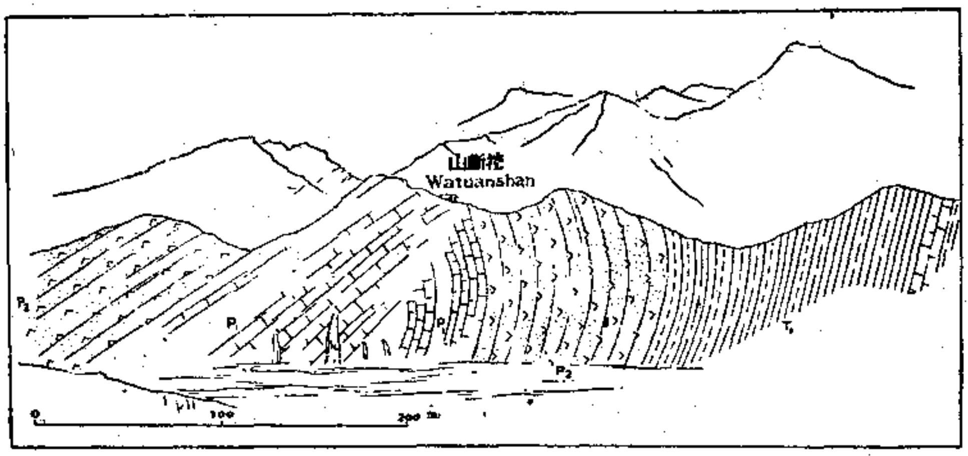
觀心頂高出海面一三〇〇公尺，其西爲震旦紀灰岩，已如上述，而廟基之下，卽接以二疊紀灰色厚層灰岩。兩種灰岩，在野外觀之，不難分辨，前者色白而硬，擊之易碎，後者色灰較柔，擊之常放瀝青臭味。二疊紀灰岩層向西北東南，傾斜向東，約二十度，沿層向踪跡而東南，與牛心寺黑龍江及新開寺等處所見，均爲一層。其與震旦紀灰岩亦爲斷層接觸，斷層延長方向，與地層層向，大致相同，可稱之爲走向斷層，東北下落爲俯側，掩沒古生代下部地層及二疊紀地層之一部，故二疊紀灰岩之露出者，不過二百餘公尺而已。觀心頂下，斜坡較陡。二疊紀灰岩之上，覆以玄武岩流，風化甚烈，所見只殘破碎屑，散佈田間，呈灰綠色，分佈不廣，寬不過二百公尺，而向東南延長，可與清音閣新開寺者連接。在玄武岩流之上，覆有飛仙關層之紫紅砂岩與頁岩，向西北傾斜，傾角約二十度，萬年寺卽位於此層之上，高出海面一〇四一公尺。

由萬年寺向北沿小徑而行，約五里，大部爲飛仙關層之紫色砂岩與頁岩，初傾向東北約二十度，厥後漸轉向北，傾角亦略減至十五度左右。至七坪之南，此紫色岩層之上，覆以白灰質脆之灰岩，薄層厚層，相間而生，卽嘉陵江灰岩也。傾斜向北，傾角由十五度至三十度，一溪自北來，橫切灰岩，成長逾里許之峽谷。逾峽而北，過七坪，卽抵羅溝，岩石爲灰色砂岩頁岩，覆於嘉

陵江灰岩之上，屬於香溪煤系，向西北傾斜，傾角甚緩。在李窰附近，尙有小煤礦數處，現仍開採，詢之礦工，據云可採之煤，計有四層，由上而下，各煤層厚度爲十六寸，十二寸，六寸，及十二寸。在洞口岩石堆上，採得植物化石數枚，惜不完整，其可辨識者，爲 Neocalamites hoerensis (Schimper)。羅溝之北，小嶺隆起，下爲香溪煤系，上卽自流井層之紫色砂岩與黏土。

由萬年寺而南，亦作短程觀察，山坡上玄武岩流二疊紀灰岩暴露，以斷層與震旦紀灰岩接觸，過石筍溝，取道牛心寺淸音閣而歸，途中所見奧陶紀頁岩砂岩，二疊紀灰岩玄武岩，仍均與震旦紀灰岩接觸，觀此益足證明地層之分佈，及構造之關係也。

萬年寺至龍門洞　由萬年寺東南行，大致沿地層層向，經金龍寺白龍洞至五顯崗，途中露頭，皆爲飛仙關層之紫色砂岩頁岩，向東北傾斜，約十度至二十度，與大峨寺中峯寺之紫色岩層露頭，傾斜相同。及行抵凉風崗，則同一地層轉向西南傾斜，傾角二十七度，其下卽玄武岩流，與萬年寺西玄武岩露頭之間，顯然成一寬緩向斜層，而飛仙關紫色岩層，位於其中。乃趙君誤認此紫色飛仙關層，爲白堊紀紅色地層，（以其下部亦呈紫色）遂推斷在白堊紀地層之下，有一大不整合在焉，但詳細考之，固非如是。漢譔依趙君之意，亦認此砂岩與頁岩爲白堊紀地層，但不信於白堊紀之前，曾有強烈之造山運動，而造成此不整合層。因彼於峨眉山之外緣，曾觀察數處，皆與香溪煤系整合接觸，而無間斷，故謂此或局部情形耳。惟事實如果認明，不必多事推論。玄武岩上，卽飛仙關層，層位關係，固一如他處，而非白堊紀地層，不整合於玄武岩之上也。凉風崗東，玄武岩流，分佈較廣，約佔六百餘公尺，乍視之頗疑其厚度大增，然細察其構造，則見地層向兩方傾斜，中成背斜層，背斜軸卽位於挖斷山村舍之側。在河谷北岸坡上，於玄武岩下，已露出二疊紀灰岩，彎起於背斜層之中心，高出水面約百公尺。然以表面灰暗，且緊包於玄武岩內，常易爲人忽視。但有足引人注意者，卽於谷壁上，現數洞孔，水由孔出，狀如瀑布，此種現象，常見於灰岩，而爲其他岩石所罕有者，倘注意及此，則不易爲玄武岩所混淆矣。此背斜層之軸面，向西傾斜，故西翼地層向西傾斜較緩，斜角三十餘度，而東翼地層，則多成直立，或覺倒轉西向。（第二圖）當時爲確悉此背斜層翼相起見，乃渡河越挖斷山而西北，至雷崖一帶觀察。介於挖斷山雷崖之間者，爲二疊紀灰岩，露出頗廣，其外卽圍以玄武岩露頭，而玄武岩之上，則爲飛仙關紫色砂岩與頁岩。沿途地



第二圖　挖斷山背斜層斜視剖面圖　P1 二叠紀棲霞灰岩　P2 峨眉山玄武岩流　T1 三叠紀飛仙關層紫色砂岩及頁岩

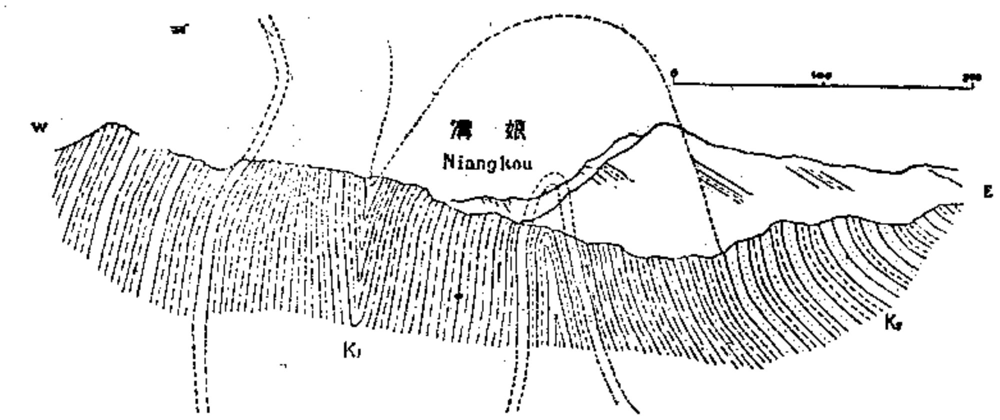
層，大致皆向東北傾斜，傾角四十度至八十餘度，爲背斜層東北翼之一部也。

涼風崗以東，玄武岩流之上，皆飛仙關層之紫色砂岩與頁岩，夾紫灰色及綠灰色灰質頁岩，層向西北東南，幾近直立，時傾於東，時傾於西。下部有灰質頁岩，夾灰岩，岩質稍硬，侵蝕之餘，成小石梁，踞河中流，形似木舟，因稱之爲石船子。再東紫灰色及綠色灰色頁岩，漸富灰質，常與薄層灰岩，夾雜而生。過鐵索橋，則大部皆爲灰岩，呈灰色，質脆而純，岩層或厚或薄，以倒轉之方向，向西南偏西傾斜，傾角七十度至八十度，沿傾斜方向而東，直至龍門洞，估面積寬約五百公尺，計其厚度，亦將近三百八十公尺，其南與鳳凰坪及雷音寺之灰岩相連，自亦屬於三叠紀嘉陵江層無疑。龍門洞者，一峽谷也，山溪東流，橫穿灰岩，成一極佳剖面。澳讀曾於此處灰岩最上部，（彼稱之爲泥灰岩）採得扁平瓣鰓類化石，及不完整之菊化石，經尹贊勳君研究，爲下列數種：

Halobia comatoides Yin
H. omeishanensis Yin
H. sp. A.
H. sp. B.
Posidonomya aff. wengensis Wissmann
? Ammonites

外線低山　龍門洞外，低山綿亘，高度大減，就測量所得，高於地面百餘公尺。與嘉陵江灰岩相接觸者，爲香溪煤系灰色砂岩與頁岩，亦向西南倒轉傾斜，傾角六十度至八十度，厚約四百公尺。與伏虎寺所見者，同屬一層，岩石性質，亦多相似，上部

黃灰色粗砂岩中，亦富含雲毋薄片，且亦無煤礦，其原因蓋亦與伏虎寺相同也。再東行至黃灣，黃灰色雲毋砂岩，漸呈棕色與紅色，然後繼以紫紅色砂岩與黏土，為紅色地層下部之自流井層。黃灣之東，則為磚紅色黏土與砂岩，當屬於紅色地層中部之嘉定層。此處地質構造，似較複雜。西部地層皆倒轉向西傾斜，與其較下之地層，均成一致。而東部地層，則復按自然順序，向東傾斜。層向為西北及東南，其間當有複雜之褶皺。渡河而北，地層暴露清晰，在娘溝一帶，詳為觀察，則見有向斜層與背斜層，共成緊壓褶皺，向斜層軸面略向西傾，故地層傾斜與其西之較古地層，尙成一致。背斜層西翼或向斜層東翼率成直立，背斜層軸面，略向東傾，故東翼地層，始近直立，繼則向東傾斜，漸東漸緩，而其上嘉定層之磚紅砂岩與黏土，已成常態，遂亦向東傾斜矣。（第三圖）



第三圖　娘溝褶皺剖面圖　K1 自流井層　K2 嘉定層

黃灣之東，邱陵更低，縣治附近，漸成平原。岩石露頭，多不可見，惟於高岡坡上，被以紅土，為由嘉定層之磚紅砂岩或黏土，風化而成。邱陵之外，率皆耕田，不復有岩層露頭，或於低地河岸，堆積近代生成之泥沙與礫石耳。

計測量調查所需時約四週，而陰雨濃霧，工作不便，往往三十公尺以外，卽視察不清，進行遲緩，而地形高下，地層分佈，非俟天晴霧散，露出眞像，不克計量觀察，因之虛耗時間，計約三分之一，有時殊覺焦灼，然亦無補於事也。

（三）地層系統

峨眉地層系統，趙君已於民國十七年夏從事觀察時，大致區分，厥後兩月，潢譚又略有改變。下自古生代前，上至中生代末，除古生代中部有一部缺失外，其他地層，大致俱備。但就作者所觀察，尙有變更及補充

者。一，九老洞層，趙君歸之於震旦紀上部，今則以改入於寒武紀下部爲宜。二，作者於趙君所稱洗象池系之上部，尋得奧陶紀三葉蟲化石，故另將其分出，名爲大乘寺層，以表示奧陶紀之存在。至漢讀所謂之志留紀者，似不能保留也。玆將各系地層，臚列於後，分別述之。（附圖第二版）

震旦紀前

花崗岩

震旦紀

洪椿坪層……八〇〇公尺

寒武紀

九老洞層……二三〇公尺

遇仙寺層……一三五公尺

洗象池層……二二〇公尺

奧陶紀

大乘寺層……一六〇公尺

二疊紀

棲霞層……四〇〇公尺

峨眉山玄武岩流……三五〇公尺

三疊紀

飛仙關層……二〇〇公尺

嘉陵江層……三八〇—四四〇公尺

侏羅紀

香溪煤系……四〇〇公尺

白堊紀

自流井層……三〇〇公尺

嘉定層……一部

第四紀

冲積層

震旦紀前

震旦紀前花崗岩　此種花崗岩，露出於洪椿坪下之溝中，或即峨眉山最古之岩石。傅思特最初發見之於峨眉崖下之四季坪，謂此花崗岩已受相當之剝蝕，表面向西南傾斜，其上以不整合之接觸，覆有沉積地層，誠如是則應爲震旦紀前者無疑。惟作者以地方不靖，未克親往觀察，頗以爲憾。僅由小溪中，採得四季坪一帶冲出之花崗岩標本，略供研究。漢讀亦謂此種花崗岩，露出於洪椿坪溝中，居峨眉山背斜層之中心，表面光滑，似受冰川之剝蝕，且有綠色基性岩壁，截止於震旦紀灰岩之下。作者亦特前往踏勘，惟以林木遮蔽，花崗岩灰岩接觸，不甚晰清，灰岩固未現特別接觸現象，而花崗岩亦無片麻組織，僅就二者觀之，誠不能定其爲後來之侵入體，抑或爲震旦紀以前之物也。至漢讀所謂之岩壁爲灰岩截斷者，曾遍訪未得，但於傅思特報告中，則謂在四季坪附近花崗岩峽谷 (Granite Gorge) 處，見有細粒岩壁，侵入於花崗岩內，疑漢讀所指，或即傅思特所見者。此種花崗岩與牛心寺黑龍江所見者相較，外表頗不相同，大致晶粒較粗，呈白綠灰或紅灰色，含淡紅色及白灰色長石，晶體長達二公分，石英與雲母顆粒較細，無殊通常所見。在顯微鏡下觀察，亦呈花崗組織，含長石甚富，斜長石較多，常現帶狀組織，正長石量稍遜，

一部變為高嶺土，石英量與正長石略同，黑雲母呈綠色或綠黃色，一部變為綠泥石，磁鐵鑛與燐灰石偶一見之。岩石常現文像組織（Graphic texture）石英晶粒每含嵌於長石之中，斜長石內，此種現像尤多。就其組織成分而言，與普通花崗岩無大差別，不能確定其為古花崗岩。惟洪椿坪灰岩之厚度，已達八百公尺，以與楊子江峽區之南陀陡山陀及燈影三部相較，厚度相埒，似已達最大數目，而灰岩之下，或應有較古岩石出現，是漢謨之說，不無可能，欲釋此疑，須待復勘也。

震旦紀

洪椿坪層　洪椿坪灰岩大都呈白色或白灰色，質硬且脆，有時含矽質。在大坪附近及洪椿坪之西，嘗於路石磨擦面上，見有圓形輪紋，徑大者約一公分，於風化面上，則現豆狀凸起，其成因不易假說，或由變質，或由風化，絕不似中國北部震旦紀灰岩中之藻類化石。傾斜緩處，常成峻嶺孤峯，分佈寬廣，約佔測量區域三分之一，厚度就測量所得，約八百公尺。

寒武紀

整合於震旦紀灰岩之上者，為寒武紀之砂岩砂質頁岩及不純灰岩等。就岩石性質，可分為三層，即九老洞層，遇仙寺層，洗象池層。層名皆趙君所擬，惟以九老洞層歸入於震旦紀，與北平西山之下馬嶺頁岩相當，不若以之歸入於寒武紀為佳，又洗象池層上部，含有與陶紀化石，故另分出，名為大乘寺層，分敘於下：

九老洞層　此層為寒武紀之最下部，岩石為灰紫色及紫黃灰色砂質頁岩砂岩，有時底部夾薄層灰岩，未曾發現化石。與洪椿坪灰岩接觸之面，在九老洞至遇仙寺中途，暴露清晰，灰岩在下，砂質頁岩在上，兩相平疊。砂岩與頁石，變質均微，下與灰岩分界顯然，應為假整合，而與其上之地層，性質相近，地層沉積，頗似連續而上。若與三峽地層相較或可相當於石牌頁岩之下部，岩石相似，亦無化石，故暫歸入於下寒武紀，全層厚度，約二百三十公尺。

遇仙寺層　此層整合於九老洞層之上，特發育於遇仙寺附近，且採得完好化石，故以名之。西至蓮花石，東至初殿，除一二稍高峯巔，被以較新之洗象池層外，大都均屬此層。岩石為灰色頁岩灰質頁岩黃灰色薄層不純灰岩及黃灰色石英質砂岩，間有紅

色薄層砂岩，覆於頂端，鲕狀灰岩，亦時可見。全層厚度，爲一四五公尺，所含化石產於距底部四十至五十公尺處，採得下列屬種：

Redlichia nobilis Walcott

Ptychoparia ligea Walcott

Omeishania yuhsienssuensis Sun (gen. & sp. nov.)

Aluta sp.

Obollela sp.

再上近於頂部，另由於黃綠色頁岩中，採得三葉蟲化石：

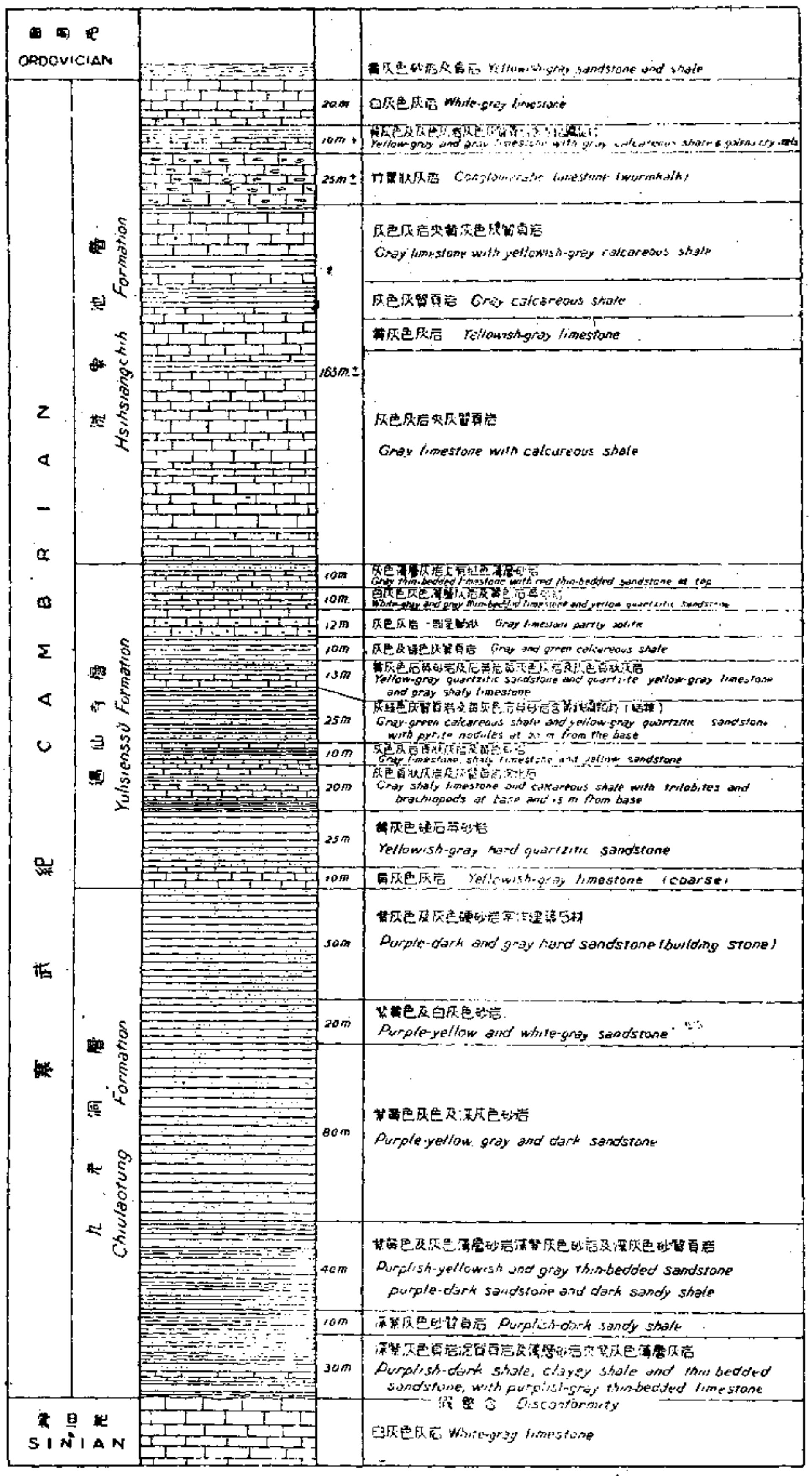
Ptychoparia szechuanensis Sun (sp. nov.)

兩處化石，均屬於下寒武紀，而後者已達其最上部。如與石牌頁岩相較，則與其上部相當。

洗象池層　此層爲寒武紀之上部，緊接於遇仙寺層之上，以灰色不純灰岩灰質頁岩及竹葉狀灰岩爲主，厚約二百二十公尺，大部匿於叢林之下，不易尋得化石。分佈狀況，與其下之二層，同向延長，經洗象池而南伸於峭崖之下，華嚴頂蓮花石一帶之高峯，亦常冠以此層之一部。

洗象池層名，原爲趙君所擬，包有下自遇仙寺層之上，上迄棲霞灰岩之下之地層，而統歸入於寒武紀。漢漠則合遇仙寺洗象池層，而另分爲二部，下部數百公尺亦歸之於寒武紀，上部約百公尺，含灰色板岩及泥灰岩，據云傅思特曾於其中採得單枝筆化石，未經確實鑑定，漢漠即據此以推其爲志留紀，與揚子江峽區之龍馬頁岩相當。然此層位於含奧陶紀化石之大乘寺層之下，若大乘寺層與峽區艾家山系相當，則此層似可與宜昌灰岩相比擬，不過以其含竹葉狀灰岩，頗類於北方寒武紀之上部，而殊於富含化石之宜昌灰岩，因未尋得化石，時代未能確定。若以此層屬於寒武紀上部，則峨眉山一帶在宜昌灰岩沉積之期，有一間斷，而

峽區則於寒武紀末期，未有沉積。反之若以此層相當於宜昌灰岩，則其厚度至此大減，與峽區比較，不過其五分之一而已。由九老洞至大乘寺途中，曾作一度觀察，茲將地層次序列如第四圖。



第四圖　峨眉山寒武紀地層柱狀圖

奧陶紀

大乘寺層　此層原爲趙君洗象池層之上部，以其發育於大乘寺附近，故以寺名。岩石以黃灰色石英質砂岩及綠色砂質頁岩爲主，下部有淺紅紫棕色石英砂岩，而上部有綠灰色頁岩，茲將在大乘寺及雷打坡所見地層次序，由下而上，簡述如下。

（1）黃淺紅及紫棕色石英砂岩夾紫紅色及綠色頁岩……………………二十公尺

（2）白灰色及淺棕色石英砂岩…………………………………………三十公尺

（3）淺黃白灰色及灰色石英質砂岩及石英岩夾綠色頁岩砂質頁岩及薄層砂岩……八十公尺

（4）淺綠灰色頁岩及砂質頁岩含三葉蟲化石……………………………三十公尺

其露頭分爲兩帶，一沿峭崖向北延長，經大乘寺至弓背山，一在雷打坡一帶，向北至牛心寺，而阻於斷層。在雷打坡所採之三葉蟲化石，經孫雲鑄君鑑定，爲下列屬種：

Taihungshania shui Sun

Acidaspis tani Sun sp. nov.

Illaenus omeishanensis Sun sp. nov.

Illaenus sp.

A Pelecypod shell (imperfect)

就上列化石而言，此層應與峽區之艾家山系相當。但峽區多灰岩，而峨眉山多砂岩與頁岩，可知當奧陶紀沉積之時，海水愈西愈淺，至峨眉山，僅沉積近海岸之頁岩砂岩耳。

二疊紀前地層沉積之間斷

覆於大乘寺層之上者，卽二疊紀之塊狀灰岩。其間如三峽之新灘頁岩，及川北之泥盆紀石炭紀灰岩，均未見於峨眉山一帶，可見自奧陶紀之末，至二疊紀之初，實有一大間斷。惟未確知者，卽各紀地層向未沉積，抑或一部沉積旋復剝蝕以去歟。但就調

查所及，地層接觸，無顯著不整合之表現，而中間為假整合者，當無疑義也。

二疊紀

棲霞層 年來國人之研究二疊紀地層者，多以棲霞灰岩代表其中部，最近黃汲清君，按化石層位，在棲霞灰岩之上，另區分一層，為茅口灰岩，合以陽新層稱之。峨眉山二疊紀地層，除棲霞灰岩外，亦有一部與茅口灰岩相當，但製圖時，尚未分出，故依其舊，統稱為棲霞層。其主要岩石，為塊狀灰岩，有時為薄層，夾黑灰色頁岩，全部厚度達四百公尺，其下以假整合覆於奧陶紀大乘寺層之上，以錘擊之，放瀝青臭味，雖含燧石結核，而量不甚多。嘗於其中，採得化石，按層位次序，可分三層。

上層 接近玄武岩流

Wentzelella timorica (Gerth)

中層 距底部較近

Cryptospirifer omeishanensis Huang

Cryptospirifer striatus Huang

Cryptospirifer semiblicatus Huang

Athyris subtriangularis (Reed)

Schizophoria sp.

下層 緊靠底部

Michelinia microstoma Yabe et Hayasaka

趙君在此灰岩中，亦採得化石兩層，下層在大乘寺附近，近於底部，計有 Tetrapora nankingensis Yoh, Stylidophyllum gnomeiense Huang, Polythecalis cf. yangtzeensis Huang, Wentzelella szechuanensis Huang, 上層採自接引殿下，而近其頂，計有

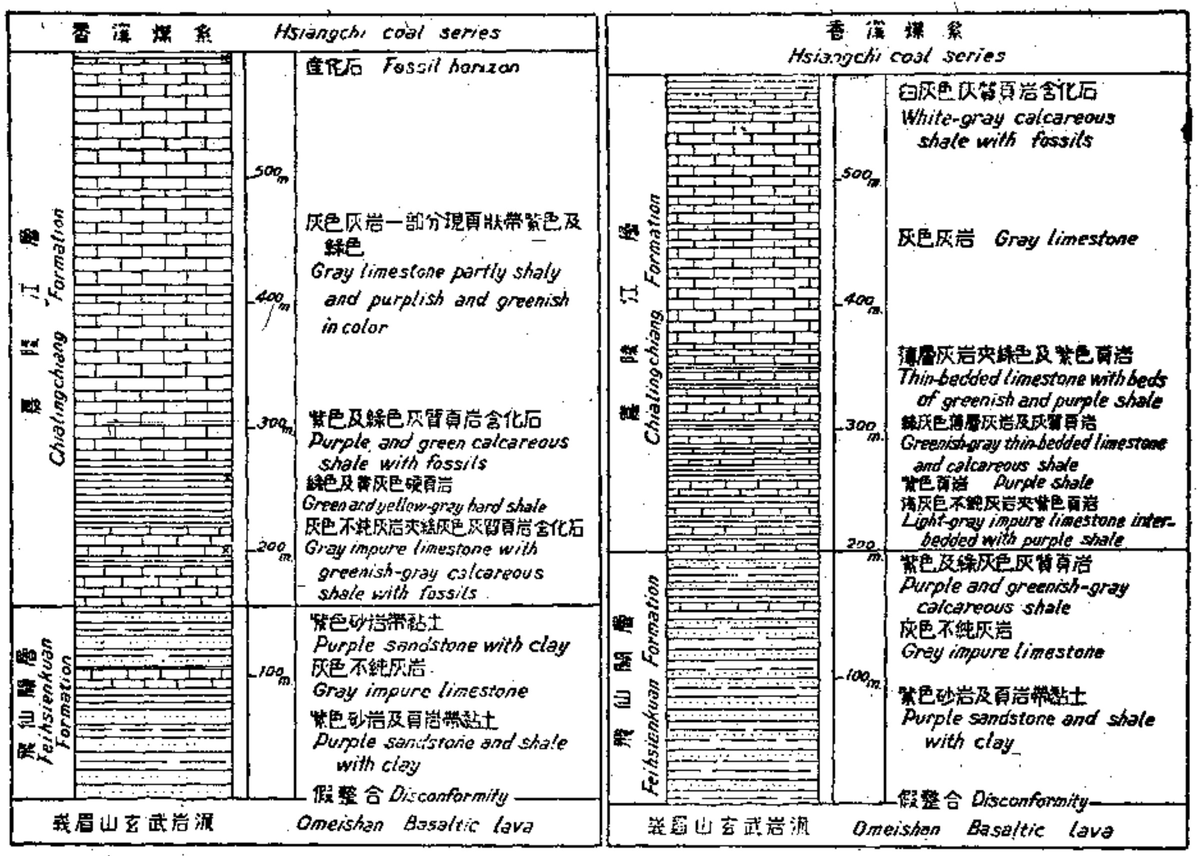
Wentzelella timorica (Gerth), Rhipidomella pecosi Marcou, Productus (Gigantella) davidi Bayan. Martinia uralica var. longa Tscheruyschew, Spirigerella cf. gandis Waagen. 按以上化石之鑑定，下層與中層屬於棲霞灰岩，上層屬於茅口灰岩。趙君所採之化石，上層屬於茅口，下層屬於棲霞。今仍稱之爲棲霞灰岩，以代表二叠紀之中部。

峨眉山玄武岩流　峨眉山頂，被以玄武岩流，分佈甚廣，隨山面緩坡，向西傾斜。而山頂以下，以斷層之影響，再露出于萬年寺清音閣一帶，分佈延長，大致平行於斷層線。涼風崗之東，亦因背斜層隆起，暴露地表。論其厚度，則各處不同，在山頂者厚達三百五十公尺，而涼風崗一帶不過百四十公尺。岩石外表，常呈深灰色或黑綠色，有時含白色細長之斜長石結晶，長可一公分，杏仁狀空體，有時可見，常充以方解石與石英，磁性甚強，當係富有含鐵鑛物所致。在顯微鏡下視之，玻璃質中，微晶甚多，爲斜長石，成白色細長晶形，無一定排列方向。在新開寺者，含橄欖石較多，成斑晶，有時含斑銅鑛。在金頂萬佛頂等處岩石，常現紅色，或由於鐵質養化之故，在顯微鏡下觀察，爲養化鐵鋁及玻璃質之混合體，呈棕紅色，而斜長石細晶，偶散佈於其內。柱狀岩理構造，偶於金頂下崖壁上見之。岩漿噴發之期，約當於上二叠紀樂平期之初。

三叠紀

飛山關層　覆於玄武岩流之上者，爲紫色或紫紅色砂岩及頁岩，上部夾薄層灰岩及灰質頁岩。飛仙關層之名，李希霍芬始用之，以代表一部紫色頁岩，而謂之爲志留紀，最近趙亞曾及黃汲清二君，重經其地，始知紫色地層應屬於下三叠紀。在峨眉山一帶，未曾採得化石，而與其上之地層連續無間，故分界不甚清晰，因之厚度不易確計，今就在龍門洞雷音寺所見，列成柱狀圖，以比較其厚度及層序，如第五圖。飛仙關層之下，與玄武岩流接觸，就表面觀之，彼此似相整合，但岩流成於地面，而厚度又各處不同，兩層中間，當爲假整合之接觸也。

此層只見於峨眉山下部，而峯巔之上地層，無新於玄武岩者。自萬年寺至龍門洞，分佈頗廣，由西北迄東南，延長約二十里，惟其中部，有小背斜層隆起，因之較古地層，露出一部。



第五圖　峨眉山龍門洞及雷音寺一帶地層柱狀圖以示兩處三疊紀地層之層序

嘉陵江層　由飛仙關層上部之紫色及綠灰色頁岩灰質頁岩，漸變而至白灰色灰岩，質純稍脆，或成塊狀，或成薄層，約厚三百八十公尺至四百四十公尺，是為嘉陵江灰岩。最初趙君謂之為昭化灰岩，厥後黃汲清君易以今名。在龍門洞峽谷中，露頭甚佳，成一天然剖面，其詳細層序，如第五圖所示。化石所在，計分三層，一層靠近底部，一層約高六十公尺，一層接近頂部，各層化石均屬于三疊紀。漢謨在最上部薄層不純灰岩內，曾採得扁平瓣鰓類化石，及菊石，已述於上。分佈於龍門洞及雷音寺一帶者，南北延長約二十里，在萬年寺北七坪附近，亦有此層露頭，組成小嶺。

侏羅紀

香溪煤系　峨眉山香溪煤系，與四川他處者大致相同，大部為灰色石英砂岩黃灰色砂岩及黑灰色頁岩，夾較薄煤層，曾採不完整之植物化石，大概均屬于三疊紀末侏羅紀初期。（Rhaetic）（見前）在其標準露頭之香溪，謝趙二君，曾以層粗粒砂岩，分為上下兩部，下部謂之 Rhaetic，上部謂之 Lias。但就作者在四川觀察所知，香溪系之頂部，與白堊紀紅

色地層之底部，多為連續沉積，無顯著分界，而紅色層下部，含有下白堊紀化石。故香溪煤系之沉積，似歷經三疊紀末期（Rhaetic）至侏羅紀，無大變動。漢護更以之代表侏羅紀全期，其言曰：「按岩石之性質乃漸進於白堊紀之紅色地層，故吾相信此含煤地層之沉積，係成於侏羅紀之全期也」。全系厚度約四百公尺。

白堊紀

自流井層　據作者所觀察四川紅色地層，可分為三部，即下部自流井層，中部嘉定層，及上部蒙山層是也。在峨眉一帶，只露出自流井層，及嘉定層之一部。自流井層，以紫紅色及綠黃灰色泥質頁岩及綠灰色雲母粗砂岩為主，與在自流井之地層，頗不相同，彼處有灰岩二層，每層均富含瓣鰓類化石，此處則耗無灰岩之跡。蓋自流井層愈西愈薄，而灰岩亦遂之而減，在自流井，灰岩發育，西北至五通橋，只有不純灰岩數公尺，西南至敘府，僅於頁岩內，見灰岩結核，至峨眉山不但灰岩絕跡，而全層厚度，亦僅約三百公尺而已。此層整合於香溪煤系之上，已如上述，雖未尋得化石，而其年代當與自流井層相同，而屬於下白堊紀，分佈於山之東麓，向南北延長，與香溪系露頭，大致平行。

嘉定層　此為紅色地層之中部，含磚紅色砂岩與黏土。在測量區域內，常成岡阜，沿山麓起伏，大部岩層，均上覆田畝，或被以紅土，頭露頗鮮。

第四紀

冲積層　不整合於各紀地層之上者，為一層結合未固之礫石層。其中礫石，大部皆石英岩，小者盈寸，大者尺餘，為橙黃色之黏土所膠着。由縣城至保甯寺新築馬路上，露頭頗多，而以峨眉與夾江兩縣中間之岡阜，更為顯著，厚約三十餘公尺。趙君以此層之堆積為成都期，謂與中國北部之馬蘭期相當。但作者就四川大部地文觀之，擬另以叠溪期名之，因在岷江上游茂縣松潘間之叠溪，礫石層最發育，而剖面亦最顯著也。

河流兩岸，及冲積平原，皆被以泥沙浮土，均為近代所成，為鬆散地層之最新者。

花崗岩

除上述各紀地層之外，尙有花崗侵入岩體兩處，其一在牛心寺之東，其一在黑龍江峽谷之南，露頭均不廣大。岩石外表，晶體較細，不似所謂震旦紀前之花崗岩，晶粒粗大。且長石皆灰白色，而非肉紅色。在顯微鏡下觀之，呈較細之花崗組織，含正長石及斜長石甚富，亦現文像組織，(Graphic texture)石英散嵌於長石內，石英量遜於長石，黑雲母量不甚多，呈黃綠色，一部變爲綠泥石。就鑛物成分而言，頗與震旦紀前花崗岩相似，而二者又均常現文像組織，亦頗相類。花崗岩侵入時期，未能確定，但四川西康各處花崗岩侵衝，影響於侏羅白堊兩紀地層，就此推論，峨眉山花崗岩，或生於第三紀初期，而在喜馬拉亞造山運動之前也。

(四) 地質構造

峨眉山位於四川盆地之西邊，高出附近低地約二千五百公尺，西以山嶺與西康西藏高原相接。大體構造，爲一寬緩背斜層，附有小褶皺，而後又受斷層之影響，茲分別述之，列舉於下：

1 峨眉山大背斜層
2 五顯崗向斜層及挖斷山背斜層
3 娘溝褶皺
4 觀心頂斷層
5 初殿斷層
6 峨眉山大斷層

1峨眉山大背斜層　此背斜層可由震旦紀灰岩傾斜方向，觀察而知。在洪椿坪溝中，灰岩向東北偏東傾斜，傾角二十度至三十二度，是爲東翼，往西不遠，又向西傾斜，傾角十度至二十五度，是爲西翼，背斜軸位於洪椿坪之西，約一里許。震旦紀灰岩

西翼之上，被以古生代地層，向西傾斜，傾角十度至十五度。而東翼古生代地層，則大部侵蝕以去。及黑龍江以東，復受斷層之影響，震旦紀灰岩，及下古生代地層，斷沒不見。在觀心頂初殿之間，按地層傾斜方向，與洪椿坪爲同一背斜層，向北延長，背斜軸位於長老坪與初殿之間，成西北東南方向，東翼地層，傾斜東北，傾角二十四度，西翼地層，傾斜西南，傾角十六度，因受觀心頂及初殿兩斷層之影響，形體不全。就此大背斜層之全體觀之，背斜軸似由東南西北方向，漸轉而爲南北方向，至其北端，而向西北傾斜焉。

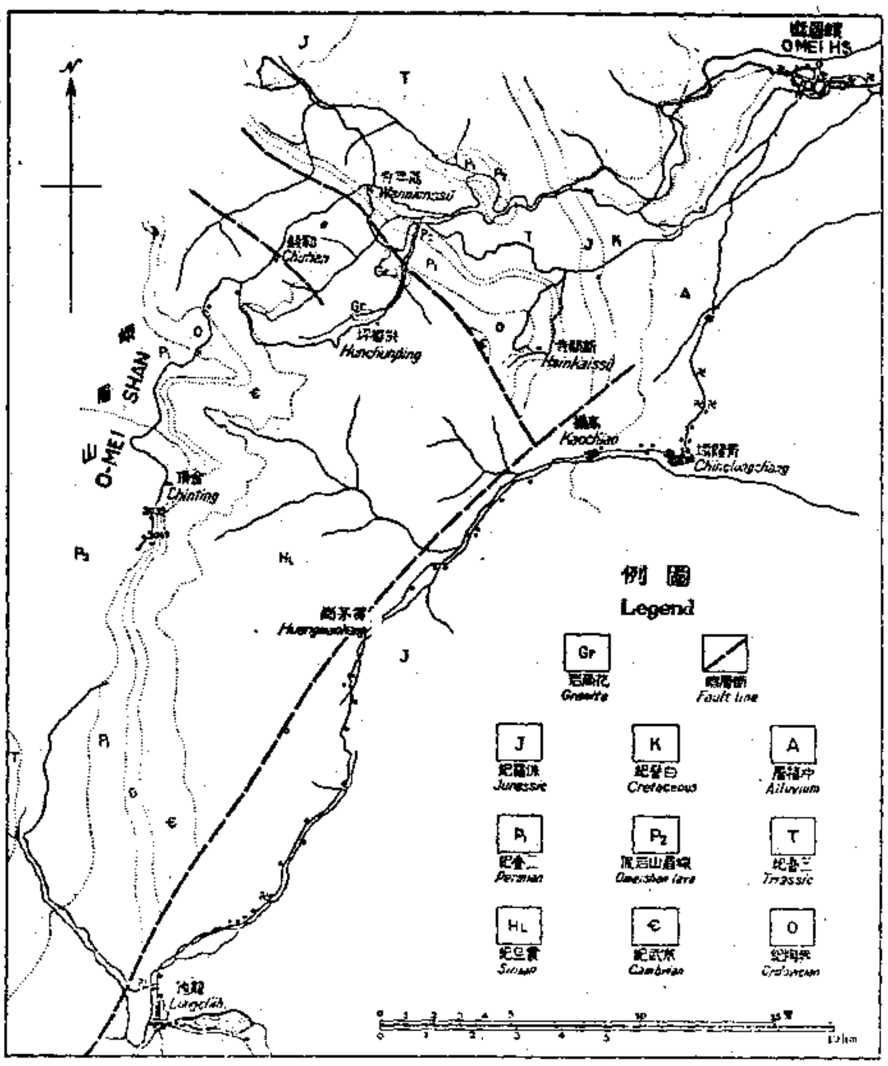
2 五顯崗向斜層及挖斷山背斜層　觀心頂斷層以東之地層，復自成褶皺，當觀心頂斷層未生成之前，此本爲峨眉山大背斜層之東翼，與大背斜層共生者，有小褶皺，厥後觀心頂斷層發生，東翼地層降落，益使褶皺緊壓，而令背斜層向東倒轉耳。五顯崗向斜層，形較寬緩，軸向爲西北至東南。大致與峨眉山大背斜層及觀心頂斷層平行，西南翼在萬年寺與白龍洞之間，地層向西北傾斜，傾角二十度，而東北翼在涼風崗一帶，地層向西南傾斜，傾角二十七度。向斜層中部，由飛仙關層之紫色頁岩與砂岩組成，而外緣爲二叠紀玄武岩流及灰岩，在飛仙關層之下，層次連續，無大間斷。接於五顯崗向斜層者，爲挖斷山背斜層，其西翼卽向斜層之東翼，二叠紀灰岩，包於背斜層之中心，其東翼地層，向東北傾斜，近於直立，或竟倒轉向西傾斜，背斜層向西北延長不遠，則成一不規則之穹窿傾斜層而盡，故其四週皆爲飛仙關層所包圍，中間露出玄武岩流環於灰岩之外。背斜層之東，由飛仙關層而上至嘉陵江灰岩，率皆成同一層向，倒轉向西傾斜，惟傾角甚大，或近直立。

3 娘濤褶皺　龍門洞之東，自流井層，倒轉向西傾斜，傾角甚大，一如其下之地層，而其東之嘉定層，則向東傾斜，愈東傾斜愈緩。介于其間者，有一緊壓褶皺，向斜層在西，背斜層在東，向西北東南延長。向斜層兩翼大致等斜，西翼地層，傾斜甚陡，一部反轉西向，而背斜層則不對稱，西翼地層幾近直立，東翼向東傾斜，傾角較緩。

4 觀心頂斷層　在觀心頂及黑龍江一帶，震旦紀灰岩，常與二叠紀灰岩及奧陶紀頁岩相接觸，中介一正斷層，斷層線大致成東南西北方向，而與震旦紀灰岩及其上地層之層向平行。斷層面雖不明顯，但由地表接觸情形觀之，傾斜甚大。斷層錯距不等，

東南較小，下古生代地層與震旦紀灰岩接觸，而西北較大，二叠紀灰岩直與震旦紀地層相接觸也。

5初殿斷層　在觀心頂斷層之西南，初殿附近，有一斷層，與其平行。斷層面雖未顯著表現，而證以遇仙寺層直接與震旦紀灰岩相接觸，九老洞層全部不見，則因斷層所致，當無問題，不過其錯距不大，不甚顯著耳。



第六圖　峨眉山略圖以示斷層線之位置

6峨眉山大斷層　峨眉山巍然高聳，峭壁數千尺，就地形視之，即可知其為斷層之崖。但斷層綫幷不緊鄰峭崖，因地層斷折後，又大受剝蝕，而成現在之地形。在由峨眉赴龍池途中，斷層線踪跡可尋，大致成西南東北方向（第六圖）。在高橋之西，侏羅紀香溪煤系地層，直接與震旦紀灰岩接觸，足證其錯距甚大，但西南至龍池之西，則香溪煤系地層，又與二叠紀地層相接，錯距較小。斷層發生時期，似在觀心頂初殿兩層以後，因觀心頂斷層實為峨眉山大斷層所阻，此種情形，就大斷層兩側地形互相比較，即可知之，在斷層仰側，均為高山，曾受觀心頂初殿二斷層之影響，踪跡尤存，而大斷層俯側，概屬低山岡阜，似未甚受前二斷層所分割，而大斷層仰側之峭壁，尚未深受剝蝕，而泯其跡也。

造山運動

峨眉山地層，下自震旦紀，上迄中生代末期，除古生代中部一部缺失外，餘均平行疊覆，無不整合，足證喀來當（Caledonian)及海西(Hercynian)二期地動，未嘗波及峨眉區域，即燕山運動，亦無顯著徵象。趙君謂燕山運動爲峨眉山之成因者，乃係誤認三疊紀飛仙關紫色砂岩頁岩爲白堊紀自流井層，直覆於二疊紀玄武岩流之上，且忽視白堊紀地層與香溪煤系之關係，視爲一不整合之接觸。故彼推論四川之造山運運，發生于白堊紀之前，而稱之爲燕山運動也。

實則紅色地層之中部—嘉定層或即屬于白堊紀之中部—已受強烈之褶皺，如娘溝一帶所見，而白堊紀與侏羅紀沉積連續，未嘗間斷，故造山運動，當在白堊紀之後，至少亦較新於嘉定層生成之期。若徵以四川他處所見，屬於紅色層上部之蒙山層，亦曾受褶皺，傾斜甚急，在名山縣一帶，蒙山層現背斜層之跡，在仁壽縣境，蒙山層傾斜有達六十餘度者。如蒙山層果屬於上白堊紀，則此區之造山運動，當在白堊紀以後矣。

作者以爲四川西部及西康一帶地殼變動，爲地下侵入岩侵衝上昇所致，由峨眉而西，花崗岩露頭頗多，有時組成高山，如果花崗岩侵入時代，在第三世初期，則地殼變動，當在其後。但除第四紀之礫石層外，未曾發見第三紀地層，故其確期，不能確定。惟於鄂西曾見東湖系砂石，傾斜不大，乃造山運動以後之物，大致在最新世以前所成。故就此推論，造山運動，似在第三紀中期，而中新世實較爲適當之時代也。按翁文灝先生燕山運動意義，不包有白堊紀以後造山運動，故峨眉山之生成，應與四川西康造山作用，同屬喜馬拉亞運動，而非燕山運動所致也。

(五)地文

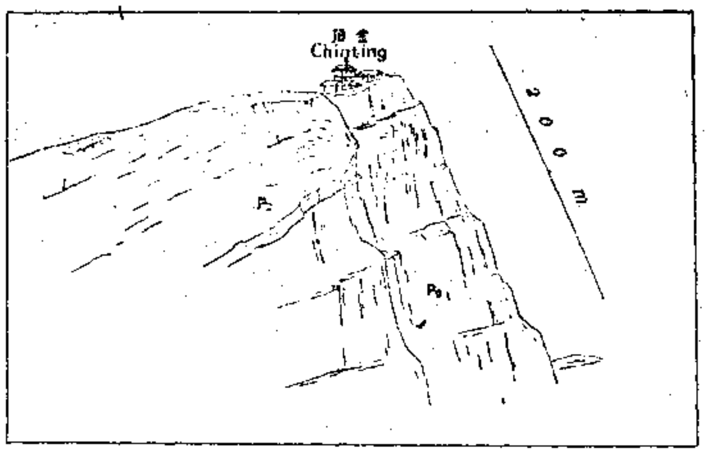
峨眉山巍然聳立，東臨四川盆地，高低之差，達二千五百公尺，大概地形，有如圖示。懸崖絕壁，峽谷急流，均足代表其幼年地文狀態。本區水系，以面積不大，故亦簡單，計有河渠三流，龍門洞河最大，清龍場河次之，而伏虎寺前之虎溪最小。龍門

洞河一源發於九老洞下，經洪椿坪至清音閣。一源發於遇仙寺下，經石筍溝至清音閣與前者會於雙飛橋下。二溪大致平行，均由西南流向東北，穿行於震旦紀灰岩內，橫貫層向，因地層率多平緩，岩石節理直立，常成峻谷峭峯，故溝以石筍名。黑龍江附近，爲二疊紀灰岩，水流沿傾斜方向，而岩石質較堅硬，故亦成峽谷，狹如夾壁。由源至此，距離不過五公里，而高低之差，竟達九百公尺，急流瀑布，所在多有。匯流而下，兩岸地層爲下三疊紀之砂岩頁岩，岩質鬆軟，谷亦寬緩。及過牛背山，折流而北，有羅溝之水來會，羅溝水經嘉陵江灰岩時，鑿成七坪峽谷，出谷後，合弓背山南坡之水，行於飛仙關層之砂岩頁岩區內，至牛背山，注於龍門洞河。紆曲而流，穿過挖斷山背斜層而東，因均橫切地層層向，故谷深且陡，而龍門洞之嘉陵江灰岩，更以石堅質膩，因成峭峽，岩層近於直立，狀如峨眉山門。出門而東，岩石鬆軟，山勢低緩，故河流紆曲，不似山行之險峻矣。　青龍場河，源出峨眉崖下，溪流而東，行經震旦紀灰岩內，谷狹而陡，及流入低地，受支流之水，折向東北，至高橋迤而東流。河中石礫磊巨，足示其流行甚急，而常有洪水也。　虎溪發源於雷打坡附近，經雷音寺而東，流過伏虎寺前。水流亦急，且橫貫岩層層向，故在高洞口穿越二疊紀灰岩，而成峽谷瀑布，過雷音寺下嘉陵江灰岩，亦成峻谷。在伏虎寺及報國寺等處，流行于香溪系之砂岩頁岩，與自流井層之砂岩黏土，雖亦時成深谷，而遠不及在灰岩中之陡峻。及過保寧寺而東，始緩行於平原中也。

綜觀上述情形，岩石性質，與地形狀態，有密切關係。灰岩較爲堅硬，故河谷亦較陡峻，本區內灰岩發育者計有三種，即震旦紀灰岩，二疊紀灰岩，與三疊紀灰岩是也。各處峽谷，均由此三種灰岩成之。花崗岩雖更堅硬，但露頭甚微，不影響於地形。古生代下部地層，大半受斷層之影響，高起而成崖壁。玄武岩橫阻溪流時，亦常成狹谷。惟三疊紀下部地層，及侏羅紀與白堊紀之砂岩頁岩黏土，均較鬆軟，河谷稍寬，然猶以河床傾斜較大，剝蝕亦深，直至流入平地，始紆曲緩行也。

地質構造，亦與水系發育有關。當大背層生成之後，兩翼坡上均有小溪，沿傾斜下流，今其西翼不在本區之內，姑置不論，而東翼率皆遵是演進。因當時觀心頂斷層尚未生成，因之挖斷山背斜層，亦不如今日之顯著，五顯崗之飛仙關砂岩頁岩，未受侵蝕，故河流能依傾斜之方向進行，不受阻梗，是爲當日之順成河。厥後觀心頂斷層發生，東側地層下落，諸小褶皺因更緊擠高聳

，狀較顯著，但河谷業已生成，且水流湍急，侵蝕迅速，故仍依原生河道進行，橫穿層向，鑿削峽谷，而其上游，更向河源侵蝕，因背斜層西翼，雖經斷落，但仍遠高於東翼，故繞逾背斜軸而西，而達九老洞遇仙寺及弓背山之下也。青龍場河之上源，原亦係於大背斜層生成之後，坡上小溪，沿傾斜流向東南，迨峨眉山大斷層發生後，沿斷層而成向東北流之河谷，納斷層以西各溪之水，故此處溪流始向東南，繼而折向東北。又以斷層關係，高低差異甚大，致各溪流向河源侵蝕，繼續向西推進，而崖上地層率多平緩，節理直立，崩潰之後，遂成削壁，而為現在峨眉山陡峻突出之形。（第七圖）虎溪甚短，發育情況不著，然遵循傾斜方向而生，亦當與龍門洞河相同，惟所異者，未受斷層之影響耳。



第七圖　峨眉山頂斜視圖以示其向西傾斜之緩坡及東側之懸崖

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粘土中輕電游子之濃度及其去水接觸之效能

衛爾遜
林卓園

土壤中輕電游子濃度之研究，對於農業頗爲重要，粘土之吸收能力及接觸作用，與酸性亦有相當關係，蓋能漂白之粘土，多有酸性作用故也。

作者用輕電極及二輕養輪質化二養輪質電極測定三十六種粘土混懸之PH值，所得結果，列成一表（見英文原文），以供比較。用二輕養輪質化二養輪質電極所測定之PH值比用輕電極所測定者略高，間亦有呈負電位差者。粘土性頗奇特，加二輕養輪質化二養輪質後，發生某種化學作用亦未可知也。

輕電極如用綠化鉑鎔液鍍之，不獨所得結果奇特異常，且鉑墨極易損壞，如用綠化鈀溶液，則結果甚佳，且每鍍一次可測定十三PH值。

酸性與吸收能力及接觸作用頗有關係，前已言之。作者用PH值由3.66至6.43之粘土四種爲接觸劑，以去酒精之水，結果所得二炭烯氣之百分率均甚高。由此可知PH值與去水接觸作用無絲毫關係也。至粘土之吸收作用等尚在研究中。

陝北油田地質

王竹泉
潘鍾祥

(一)緒言

民國十二年泉曾由陝西東北隅之府谷縣，西南行經榆林而抵靖邊，復折而東行，越綏德而至黃河右岸之吳堡縣。斯役不僅將從前全國煤油礦公署所延美國煤油技師馬棟臣(F. G. CLAPP)及王國棟(M. L. FULLER)所稱之石炭紀陝西系，由植物化石證明而知其確爲下侏羅紀，且彼等之二疊紀安定灰岩，因有魚類化石之發現，而知其實爲上侏羅紀。

民國二十一年夏，泉等復因國防設計委員會之委託，至陝北勘察石油，彙調查吳堡清澗安定膚施延川延長等縣地質。此次旅行因區域之廣汛，時間之短促，亦爲一初步之工作，全行雖費四十二日，而野外實地工作之時間，僅二十日耳。

此次本擬用平板測量及計步方法，作一沿路之地質圖。後因從前美國煤油技師所測二十一萬一千二百分之一路綫圖，及參謀部陸地測量局所製十萬分之一地形圖，尚可應用，遂利用該圖。沿途除研究含油地層之岩石性質及地質構造外，並詳勘各地之油苗，且於各層中尋找植物化石，以研究此含油層之地質時代。

(二)地質概略

西曆一千九百十四年至一千九百十五年，美國地質學家馬棟臣及王國棟首來陝北勘察石油，彼將地質分類如下：

一，山西系　灰色砂岩頁岩及煤層。

二，汾河系　紅色砂岩。

三，陝西系　灰色砂岩及頁岩，含薄煤層及石油。

以上三者屬石炭紀。

四，紅色頁岩砂岩及薄層灰岩，　二疊紀。

五，紅色砂岩，　二叠三叠紀。

以上地質時代，係根據美孚公司煤油技師陝北調查報告底稿，現存於實業部者。至民國十二年因泉將各處所採集植物化石鑑定，乃將彼之山西系及汾河系以上之地層，分類如下。

一，下侏羅紀煤系。

二，紅色頁岩及砂岩，　大概屬於中侏羅紀或上侏羅紀。

三，薄層灰岩，　上侏羅紀。

四，紅色斜層砂岩，　上侏羅紀之上部以至白堊紀。

因石油均含於下侏羅紀煤系，所以此篇大部分均是討論此系，以及關於含油層及油苗等問題，茲先將沿途所經之路綫，述之。

(三)路綫

敍述路綫之先，陝北之地形，不可不先爲述之。陝北爲一侵蝕高原，侵蝕之力極盛，嘗構成深谷狹川，分高原爲若干之小平台，高出海面自三千五百尺至四千尺，距谷底約由三百尺至五百尺。地質均爲中生代之地層，上爲由數十尺至數百尺之黃土及紅土所覆。設在黃河附近登此高原之上，則可見此高原之全景，其東在山西境內，則重巒疊嶂，環繞羅列，均爲寒武奧陶紀灰岩所組成，乃高原之基底。所以欲述此高原，須自覆於灰岩以上之地層起首，因此山西離石縣西之柳林鎮，似爲一合宜之起點。

甲，柳林鎮至吳堡縣　柳林鎮位於陝北高原東緣石炭二叠紀煤系之上，該煤系傾斜平緩，大致均向西。自此西行至吳堡縣，岩層可分三系，最初則見大部均爲黃綠色頁岩，次見紅色頁岩間夾薄層淡紅色砂岩，終見紅色砂岩及薄層紅色頁岩。從此前二系中，泉於民國九年，曾在山西之保德縣，(位於柳林鎮之北約一百八十公里)採有很多之植物化石，頗可證明其屬于二叠紀及二叠三叠紀。此後一系尚可分爲二部，下部多爲石英顆粒所組成，上部在黃河附近則多爲長石顆粒所組成，可稱之爲長石砂岩，此

系之地質時代，因無化石證明，暫歸之於三叠紀中。自柳林鎮吳堡縣本有一很好之汽車路，因當經過時，柳林鎮之東一部汽車路爲大雨冲壞，未能通行。

乙，吳堡縣至清澗縣　吳堡縣城位於黃河西岸之岩崖上，岩石爲三叠紀之紅色砂岩及頁岩，城甚荒凉，居民不過四十家，夏日水漲時，黃河奔流之波濤聲音，城內居民聞之甚清。由太原至楡林之大道，經此城南十里之宋家川。自宋家川至清澗縣有二路可行。一爲西行經義合鎮綏德縣而至清澗縣，路程約二百四十里。一爲西南行經棗林坪店子溝，此路稍近，約二百里，惟不及前路之易行。泉等所行之路，除由宋家川至棗林坪三十里爲順後路外，其餘則另順一小道而行，此段岩層爲紅色長石砂岩，間夾少許紅色及綠色頁岩。

自棗林坪西南行爲順一深狹之河溝，上下侵蝕之力極盛，小路常在此狹溝稍上面之寬處，此寬處亦可代表一較老之侵蝕期。沿途所見長石砂岩嘗成斜層狀，漸行則見其中所夾之紅色頁岩漸少，而漸爲綠色泥質頁岩所替代，直至棗林坪之西南八里，則紅色頁岩完全不見，均爲綠色砂岩及頁岩，夾少許之黑色頁岩，自此以上可歸之於上三叠紀。因岩石改變如此之漸，所以自下三叠紀至上三叠紀，無一定顯明之界限。在此上三叠紀黑色頁岩中，偶可發現植物化石之遺跡，惟未見完美者。自棗林坪西南行至十二里之處，即須上一黃土嶺，嶺長約十八里，嶺上均爲黃土及紅土，岩層均爲所蔽，惟於深溝中能見之。逾土嶺即至無定河，其幼年期之峽谷，亦可看見，惟河谷稍寬，且河谷之旁已開成田，因夏日雨大，岸旁之田多被淹沒。自此南行至川口鎮，路長約六十里，最稱難行，因須越數土嶺深谷，行路維艱，岩層仍爲長石砂岩及綠色薄層頁岩，砂岩常成斜層狀。自川口鎮西行沿一河谷，道路平坦易行，河谷亦爲一幼年期之峽谷，侵蝕盛行，岩層露頭頗佳，傾斜向西約三四度。川口鎮之西相距約四十里，有一村曰白李家河，在地質上頗爲重要，因自此村以西，則長石砂岩即變爲灰色及綠色石英砂岩與綠色頁岩之互層。更西行越一土嶺，即至清澗縣，岩層多爲黃土及紅土所覆，露頭罕見，但幼年期之峽谷，到處皆是。此次在清澗縣城外於灰色砂岩所夾之一薄層灰黑色頁岩中，採有下列各種植物化石。

Bernoullia cf.

Voltzia cf *heterophylla* Brongn.

Voltzia sp.

Amentum sp.

時代應屬於三疊紀。

總之自聚林坪至清澗縣，砂岩中嘗夾有黑色頁岩，偶含植物化石，但無可開採之煤層。砂岩最多，嘗成斜層狀。自李家河以東，砂岩多為長石砂岩，自李家河以西，砂岩多為石英砂岩。自下三疊紀以至上三疊紀，岩石由紅而漸變為灰綠，無一定之界限。地質構造極簡單，傾斜向西普通由三度至四度。上下侵蝕力極強，是以嘗成峽谷瀑布，以致小路非順溝底，嘗在溝之半坡。

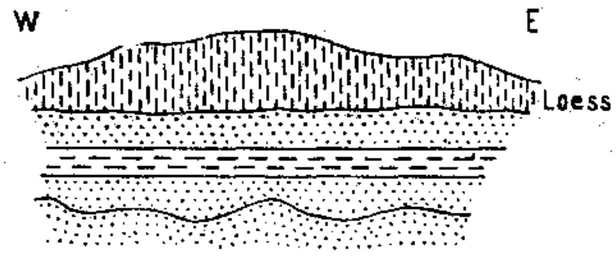
丙，清澗縣至膚施縣　　自清澗至膚施之大道，應經延川，但泉等為看地質起見，繞道永平鎮。自此復西北行而至瓦窰堡，更南行而至膚施縣。全路約三百三十里。自清澗西南行不數里即須登嶺，逾嶺而下，順永平川即至永平鎮，為一日之路程，約八十里，岩層時隱時現，傾角小，傾斜向西。在永平鎮之東二十里，有一村曰馮家坪，其岩層成一微小之穹地，傾斜向四周約三四度。距永平鎮之東十里，有一村曰石油溝者，油苗遠發現於六百年以前之元朝。石油溝位於一溝口，在此村之東約二里，有油苗發現於永平川之川中，現土人掘有油池，深約三尺，有油泡從一層灰色細砂質頁岩中隨泉湧出，此油泡聚集於水面，而成一黑色油層，土人用碗取之，以作燃燈之用，聞每日可取油八斤。在此含油層之上，有煤一層，露頭約二寸，似亦含有石油。在此油苗之東五十公尺處，泉等發現另一油苗，石油亦出自一層灰色細砂質頁岩中，厚約四尺，油泡湧出較稀，似不及前層（上層）油苗之旺。在此二油層之間，為一層灰色硬砂岩，厚度至少有一公尺。除以上二油苗外，在油苗之西，河中尚有一油苗，惟當時適值夏日，為泥所淤。其附近有一煤窰廢井，聞煤厚約二尺，為有煙煤。在石油溝之西約五里，有一村曰李家溝，有一小煤窰，土人現尚開掘，煤層厚約一尺八寸，亦為有煙煤，曾取有煤樣，以備化驗，按地層上言之，含油層適在此煤層之下也。

自永平鎮西北行至瓦窰堡，溯一河溝而上，當距瓦窰堡約二十里時，須越一土嶺，下嶺即至瓦窰堡。略言之，此段岩層之露

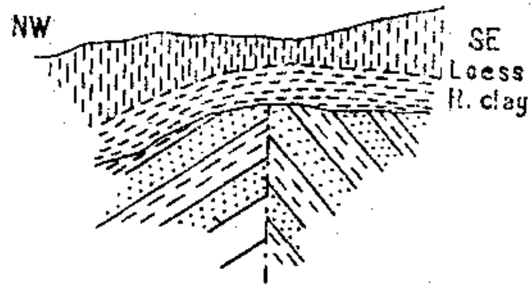
頭不佳，一半因爲黃土所覆，一半因上下侵蝕力不強。在高家屯及崖頭村之間，見有許多之煤窰廢井，可知在李家溝煤層之上，尙有許多之煤層也。岩層傾角在他處嘗爲三四度，很少超過四度者，但在崖頭村，傾角則較大約十度左右。

在崖頭村之西灰色砂岩中，見有局部侵蝕之遺跡（第一圖），此可表示當岩層沉積時，並非連續不斷，而有暫時之間斷。岑灣之西北，岩層忽變爲直立，無一定之傾向，蓋爲一斷層所致（第二圖），至於此斷層之性質，似乎爲正斷層之一種，斷距不大，其詳尙待詳究。

自瓦窰堡至膚施縣，泉等本擬經安定安塞而行，藉研究煤系以上較新之地層。但因由安定至安塞之間，土匪猖獗，不得已遂改道蟠龍，直奔膚施，全程一百八十里。沿途雖須經三小土嶺，岩層露頭尙佳，大致爲順岩層之走向而行，舊窰頗多。在金川口與蟠龍鎮之間，有一薄層黑色炭質頁岩，夾於砂岩及頁岩之間，質甚輕軟，土人嘗用以作裝飾品，如手鐲杯盤等類。此頁岩磨成薄片，在顯微鏡下視之，見有很多之微小質點，如藻類然，並經化驗含有油質，此頁岩當屬油母頁岩層。（參閱第七章油母頁岩）



第一圖　延川崖頭村西砂岩中侵蝕面



第二圖　延川岑灣西北之斷層

丁，膚施縣至延長縣　膚施附近聞有許多之油苗，但當著者調查時，可見者僅二。一在城南二十五里之溝門上，油苗發現於大道旁之河溝中，土人掘土成池，油則漸漸湧出，成一層黑色油層，浮於水面，每日可取油七八斤，以作燃燈之用，油爲出自一層細灰色砂岩中。另一油苗在城西二十里之拚家莊，油出自河旁石崖下砂岩層及節理中，（第三圖及第六版第一圖）並有少許之。泡，有時遂油湧出，油則浮於水面，而成一層黑色黏質薄膜，陝北油苗之帶汽泡者，僅見於此。此含油層按地層上言之，則較高於溝門上之含油層。在此二油層之間，董家溝侯家

溝夏家嶺等村，亦曾發現油苗，但現在均爲泥土所覆，所以膚施附近至少有油層三層。岩層大部爲灰色砂岩及灰綠色頁岩，傾斜向西或西南，傾角很小。在排家莊西面砂岩中，嘗現很美麗之波痕。自膚施以西雖很薄之煤如一二寸者，亦常常見到，但無可開採之煤層。

由膚施至延長之大道，爲順延水而東下。此處延水溝谷頗寬（第六版第二圖）上下侵蝕力不若他處之顯著。岩層傾斜小，傾角約由三度至四度。膚施東十里有一村曰喬兒溝，美人曾在此掘一井（第六版第三圖）深約三千尺，聞僅見少許之油跡，因此處在膚施各油層之下，其未見油無足怪也。自喬兒溝東行至黑家鋪，約一百里，其間煤層現爲土人所開採者有四，皆爲有烟煤。最上層採於距城十五里之劉王家溝，厚約二尺，第二層採拐於峁（第六版第四圖）在城東三十里，厚約一尺五寸，第三層爲採於距城東五十里之白家崖，煤質較好，出產亦較多，沿途常見許多驢騾，馱煤往膚施縣城。在延長之西南六十里，有一村曰石馬科者，現亦產煤，厚約二尺，亦爲有烟煤，此煤層未知與第三層係一層抑係另外一層，其關係不大清楚，或者較第三層稍下而爲最下之一煤層。此次於拐峁鎮之西五里，有一村曰崖李家坪者，採有下列各種植物化石：

Cladophlebis (todites) williamsoni Brongn, forma whitbiensis Lower Oolitic-Rhaetic.

cf Baiera taeniata F. Braun. Lower Liassic-Rhaetic

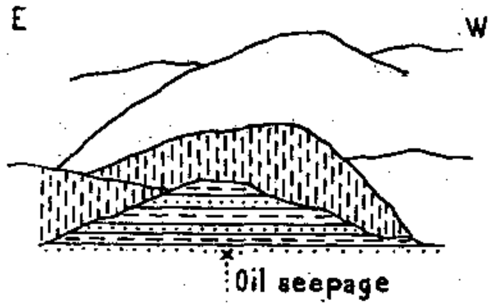
Baiera sp.

Sagenopteris nilssoniana Brongn, sp. Liassic-Rhaetic

Pityophyllom nordenskioldi. (Heer) Jurassic

時代應屬於下侏羅紀及下侏羅紀與三叠紀之過渡層。

白家崖之東有一小村曰楊家圪，（東距延長約九十里）此村在地質上亦頗重要。因在此村之西，岩層爲灰色砂岩黑色或綠色頁岩及煤層，在此村之東岩層則爲灰色與灰綠色砂岩及綠色頁岩，無



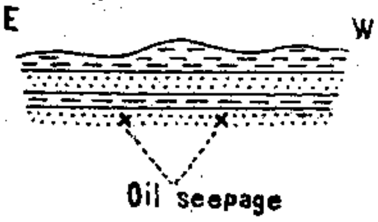
第三圖　膚施排家莊東南含油層

可開採之煤。前者屬於下侏羅紀，其底部砂岩現露於楊家坬至姚店子之間者，厚度頗大。後者從前泉會一同歸之於下侏羅紀煤系，因後者亦爲灰色砂岩及綠色頁岩，並少許之薄煤層，此錯誤美國煤油技師於其最近著作中，亦誤用之，但此次在淸澗縣及延長縣採有很多之化石，證明後者屬于上或中三叠紀。

自黑家鋪至延長縣有二路可行，其一爲順延水而下，其一爲越一土嶺，因後者較近，泉等乃從後者。及至登土嶺之頂，見其爲一很奇特之黃土高原，山頂瀰平，均爲耕田及村落，不過爲無數之深溝分爲若干之小平台而已，設使一人忘其登山之苦，則彼必誤認爲仍在平地，而不知其身已在山上矣。岩石露頭不佳，大部仍爲灰色及灰綠色砂岩與頁岩，砂岩嘗成斜層狀。

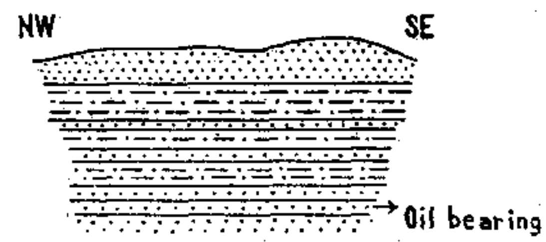
延長縣爲陝北產油之中心，其附近曾發見很多油苗，但當著者調查時，僅有五處可見，約可分之爲四層。第一層即最上層位於城西南十五里之喬家石科，（第四圖及第七版第一圖）油苗出現於新近侵蝕之狹溝中，出油處嘗有黑色黏質留於石上，含油層爲一種薄層灰色砂岩，厚約三四尺，但此砂岩順其走向不遠，即變爲砂質頁岩，所以此油層恐不甚普遍。第二層出現於延長縣城西門外，石油官廠第一井即位於此，當著者調查時，油苗適爲泥土所淤，僅有少許之油出現於土上，此層較低於喬家石科油層。第三層位於城東北十里之煙霧溝，油泡順泉湧出，浮於水面，而成一層黑色油層。每日可出油數斤，曾取有油樣，以備化驗，油爲出自一種細質薄層砂岩之層縫中。（第七版第二圖）在此油苗之南，約一百公尺之河溝中，亦有少許油苗出現。在此油苗之北六里處，美人曾掘油井一，據土人云當時每日出油二百斤，但現在此井已爲土所填，僅有遺留之鐵管及破屋基。（第七版第三圖及第八版第一圖）東南行順烟霧溝而下，至煙霧溝與延水交會處，有一村曰呼家川，於此村之北面溝中，見一層細質薄層砂岩上，亦帶有黑色油質，砂岩厚約〇．八公尺。（第五圖及第八版第二圖）此層與烟霧溝油層是否係一油層，尙不甚清楚。自呼家川順延水東下十里，有一村曰廖子原，有少許之油苗，出自村南溝中，含油層爲一種斜層灰色砂岩，厚約四公尺，此層可稱之爲第四層，爲油層之最下者。（第六圖及第八版第三圖）

第四圖



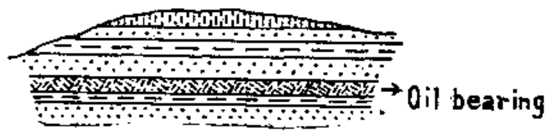
延長喬家石科東含油層

第五圖



延長呼家川西北含油層（細粒砂岩）

第六圖



延長廖子原東南含油層（十字層砂岩）

延長附近之岩層，雖大致傾斜甚緩，然經詳細研究之後，則知其為一很平緩之背斜層。背斜軸大致為東西向，其北翼傾斜向北一二度，南翼則傾斜向南一二度，所述五油苗則分佈於其軸部。此次在延長城西約六里之處，有一村曰懷林坪者，於其北面延水北岸之灰色頁岩中，採有下列植物化石：

Schizoneura paradoxa Schimper. Buntsandstein-Keuper.

Equisetites sp.

Asterocarpus virginiensis Var. obtusilobus Fontaine. Rhaetic

Dichopteris sp.

Amentum sp.

Aethophyllum sp.

以上各化石因大部為新種，故其真實之層位，難以確定，惟就其屬之性質言之，似均為三疊紀之產物。

戊，由延長至山西永和縣及石口鎮　由延長至山西之石口鎮，因路行甚速，現在僅能將沿途所見之大概，約略言之。自延長至交口鎮，岩層大部為灰色砂岩及綠色頁石，砂岩則常成斜層狀。自交口鎮經延水關至永和縣西三十里處，岩層大部為長石砂岩及綠色頁岩。所見岩層悉屬於上三疊紀或中三疊紀。自永和縣至石口鎮，均為紅色砂岩與頁岩，玆暫歸之於下三疊紀中。石口鎮以東為寒武奧陶紀灰岩，嘗成高山峻嶺，圍繞於中生代岩層之東，構成陝北高原之邊緣，其與下三疊紀紅色岩層，成正斷層之接觸，以致石炭二疊紀煤系岩層，在此不可復見。

(四)油層

陝北除其南部近渭河盆地為近生代沉積外，全為中生代之地層。岩層平緩，傾斜普通向西由一二度至三四度。重大之摺曲，

雖非全無，實例甚少，惟微小之斷層，則甚常見，且近斷層之岩層每多直立。此次在延長清澗悉採有植物化石多種，頗關重要，因從前所謂下侏羅紀煤系下部者，現由植物化石證明，而知其爲三叠紀。茲爲明瞭各油層之地質關係起見，乃先將中生代地層重述之如下：

一，下三叠紀紅色岩層　此系整合覆於石炭二叠紀煤系之上，下部爲紅色頁岩與紅色砂岩之互層，中部爲紅色砂岩及薄層紅色頁岩，上部則爲長石砂岩及薄層紅綠色頁岩。全系厚度，約六百公尺至八百公尺。泉前在山西保德縣，曾於此系之下部，採得植物化石頗夥。

二，上三叠紀或中三叠紀灰色砂岩及綠色頁岩　此系整合覆於下三叠紀紅色岩層之上，從前均歸之於下侏羅紀煤系中，現由植物化石證明，而知其應屬於上三叠紀或中三叠紀。下部岩層大部爲長石砂岩間夾綠色或黑色頁岩，上部爲灰色石英砂岩及綠或黑色頁岩等。全系厚度，若按傾斜一度計算，約達一千公尺，此不過一約略估計之數，因許多局部之變動尚未計也。尚有一點，頗稱特別，足以注意者，卽岩層常成局部之不連續，岩石之性質與厚度，亦常常變化，此現象或者因當岩層沉積時，係一種三角洲沉積之故。

三，下侏羅紀及中侏羅紀煤系　此系爲灰色砂岩綠色或黑色頁岩及煤層所組成，其厚度若仍按傾角一度計算，約達八百公尺。現所開之煤層有四，均厚約二尺左右，但在鄂爾多斯準噶爾及府谷神木間之鎮羌堡永興堡等處，煤層有時厚達十八尺，在膚施東二十五里之崖李家坪採有植物化石數種，似屬於下侏羅紀或下侏羅紀與三叠紀之過渡層。前於民國十二年時，在橫山縣之東北下爛泥灣，於此系之上部，曾採有 Dioonites Brongniarti Seward 一種，屬於中侏羅紀，所以此系之上部，其不含可開採之煤層者，頗有屬於中侏羅紀之可能。

陝油層大致可別爲三組，其二組含於上三叠紀或中三叠紀灰色砂岩與頁岩中，一組含於下侏羅紀煤系。最下組發現於延長附近，可稱之爲延長組，含有油層四層，其由下而上數之第三層，卽現在延長石油廠所開採之油層。中組發現於延川縣之永平鎮

，可稱之爲永平組，含有油層二層。上組含有油層三層，均在膚施附近，可稱之爲膚施組。陝北油苗雖有三組，而現經開掘者，僅延長一處，其餘二組均尚未經開掘試探，故究竟何組含油較富，頗難推測，若就油苗觀之，似乎中組與下組含油較豐，換言之，即上三叠紀或中三疊紀中二組，所含油量，似較豐富也。

各油苗中之石油，均出自灰色砂岩之層面或裂縫，砂粒間之細孔，則含油絕少，所以各油層中之石油，大致均非原含石油，頗似由其他油層中遷移而來，至於均自何層遷移而來，此問題頗偏理論，自甚難言。現假定有生油層二，雖尚未有充分之證明，但頗近理。一在延長縣之東南，距黃河約六十里之處，爲一層黑色頁岩，厚約六寸，謝家榮先生在此層中曾採有許多魚類之鱗片及葉肥類化石，彼並主張此頁岩爲生油岩層，應以爲石油之來源。延長組及永平組含油層，按地層上言之，均在此頁岩之上，所以此頁岩亦許與石油之生成，有密切之關係。一在下侏羅紀煤系中，蓋煤系中自下而上數之第三煤層上，有數薄層黑色油母頁岩質甚輕軟，將此頁岩磨成薄片，在顯微鏡下視之，見有許多之微小質點，此層適在膚施組含油層之下，頗似爲膚施油苗之來源。

(五) 延長石油官廠概略

延長石油官廠第一油井即現在廠中之老井，(第八版第四圖)爲開自清光緒三十三年。當時延長縣知縣洪寅彙油廠提調，聘日人佐藤彌市郎爲技師勘測老井探油地點，掘深至二百二十六尺即抵油層。當時每日出油二三百斤，至民國五六年時，每日增至一千七百斤或二千斤，以後復漸漸減少現每日出油約二三百斤。

宣統三年二月在距城二十五里之舍利莊，掘第二井，深至三百二十尺，日可出油二三百斤，現已作廢。同年在第一井迤北高坡上，掘第三井，當深至三百尺时，見油少許，至五百四十九尺反而無油，遂停工。

民國四年美人在城東北十里之烟霧溝試掘油井，聞初開時日可出油二百斤，現已作廢。

民國十三年油廠總理趙國賓以人力掘井法於縣西門內，試掘第五油井，至十五年已掘深三十餘丈，尚未見油，遂停工。繼復在東廠後山，以機器開掘第六油井，深三十餘丈。曾見油苗，初時油量尚佳，繼日見減少，乃改用人力採取。

民國十八年現任監督包恩駼於第一油井西北三百公尺之處，掘一新井深五百二十尺。最初每日可出油六七千斤，最多者則至萬五千斤，後復漸漸減少，現每日出油僅一百餘斤耳。玆將延長石油官廠第一油井歷年出產原油數量列後：

年別	原油數量
光緒三十三年	六〇，〇〇〇斤
光緒三十四年	一五〇，〇〇〇斤
宣統元年	一四〇，〇〇〇斤
宣統二年	一六〇，〇〇〇斤
宣統三年	九〇，〇〇〇斤
民國元年	六五，〇〇〇斤
民國二年	二八八，〇〇〇斤
民國三年	二三〇，〇〇〇斤
民國四年	四〇〇，〇〇〇斤
民國五年	六三〇，〇〇〇斤
民國六年	六四〇，〇〇〇斤
民國七年	三三〇，〇〇〇斤
民國八年	二三〇，〇〇〇斤
民國九年	一九〇，〇〇〇斤
民國十年	三五〇，〇〇〇斤

（以上據十年出版之延長油礦開鑿新井預算書）

民國十一年	三七〇，〇〇〇斤
民國十二年	三〇〇，〇〇〇斤
民國十三年	三四〇，〇〇〇斤
民國十四年	二九五，〇〇〇斤
民國十五年	二四〇，〇〇〇斤
民國十六年	二五〇，〇〇〇斤
民國十七年	二三〇，〇〇〇斤
民國十八年	一七〇，四四八斤（以下爲第一井及新井合計之產量）
民國十九年	二六二，六一〇斤
民國二十年	一三二，五一〇斤

原油經提煉後，可得各種油類。大約每原油千斤可煉出揮發油七斤，汽油三十四斤，甲等燈油四百一十七斤，乙等燈油（又名安全油）三百二十四斤，白臘油一百八十斤。

延長石油官廠之組織及營業　廠設監督一人，總理廠內一切事務，內部計分三科，（一）總務科，分文牘股會計股庶務股營業股，每股各設主任一人。（二）工務科設科長一人，及採取股主任一人。（三）製煉科分製煉股設有主任一人，辦事員三人，司事一人，炭窰經理一人。廠內設有總領工一名，管理各部領工及工人二十餘名。全廠職工合計約三十餘名。茲將其近三年營業收入支出數目列表於後，庶可窺其營業之大概。

民國十八年	收入二六，七一六元
	支出一三，四〇二元

民國十九年	收入	二九，一九七元
	支出	一八，〇四四元
民國二十年	收入	二〇，九三二元
	支出	一八，一九九元

(六)預擬試探地點

陝北自清光緒三十三年第一井開掘成功以來，一般人士均以為陝北含油甚富，政府亦極力設法採掘，後經美國煤油技師之調查及試探，則復覺其油量未見豐富，恆置之不甚注意。泉等以為中國油田既少，需要又殷，陝北實尚有試探之必要。因石油嘗因岩石性質及構造之關係，變化極巨，非經試探以後，不能知其確實之價值。普通定油井之位置，多注重地質構造，但陝北油田之地層，率皆平緩，除延長油井似乎在一平緩之背斜層軸部外，欲找一適宜之大背斜層構造，極不易得。茲按油苗含油之狀況，擬定油井數處，以備將來試探之參考。（一）在延長東門外之雷家灘。（二）在永平鎮東十里之石油溝。前者暫擬四井。後者暫擬六井。各井地點之詳細分布可參看附圖。設此數井試探成功，則煙霧溝喬家石科溝門上以及排家莊等地，均可依次試探也。

(七)油母頁岩發見

陝北油母頁岩，據本所燃料研究室化驗，含油可至百分之九·五，即每噸頁岩均可含油五十三加侖，頗有開採之價值。此含油頁岩之存在，本地居人並無知者，前次美孚採礦之美國技師亦未注意及此，直至泉等調查將標本攜歸試驗始發見之。且此頁岩露頭北起自橫山縣東南之麒麟溝，南達膚施安定二縣間之蟠龍鎮，延布二百里（見第一版地質圖）面積甚廣。向北及向南均尚有延長之希望。此次所試驗之標本來自橫山之麒麟溝，其地此頁岩總厚約四尺但分為數小層，各厚自數寸至一尺，中夾無油之砂岩。在膚施安定二縣間之蟠龍鎮，則此頁岩厚度增大，總厚約五·六尺。向南為黃土所蓋，但如果詳細探查，當仍可發見露頭。此頁岩含油成分照上分析實足稱為上等，分布又如此之廣，厚度雖不大而傾斜甚小，故可採之面積亦極大。

前二次調査因在野外於此頁岩之重要尙未充份注意。故觀察未及十分詳細。但麒麟鎭及蟠龍鎭二處則觀察甚爲可靠，而從地質構造上推想，其間之連續又極有把握。惟所試驗之標本恐係其中之最富者，其餘部份是否同一成份則非再加調査試驗尙難斷言。今姑約略估計其可能之儲量以見大凡。假定傾斜約十度，可採深度爲三百公尺，可採之東西寬度爲二千四百公尺，南北長度即僅就麒麟溝至蟠龍鎭間之距離計算已約有一百公里。如此則可採之面積爲二萬四千萬平方公尺。再假定油母頁岩平均厚度爲一公尺，比重爲二·五，則共有油母頁岩六萬萬噸。照以上分析，每噸頁岩含油五十三加倫，假定平均只有此數之半即二十六加倫，則共可有油一百五十六萬萬加倫即三萬七千萬桶（Barell）。照此計算，實足稱爲中國之一極大油源。但此僅係初測結果，尙須繼續研究庶可知其究竟也。

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A STUDY ON COKING PROPERTIES OF SHENGKENGSHAN COAL BLENDED WITH OTHER BETTER COKING COALS.

K. Y. KING.

ABSTRACT.

The purpose of this study is to find the possibility of the Shengkengshan coal for the production of metallurgical coke for the proposed iron and steel industry on lower Yangtze.

Agglutinating power, low temperature carbonization, and horizontal gas retort tests have been applied to verify the possibilities of different coal blends.

Conclusions drawn are based upon the results of the tests that it seems hopeful to blend Shengkengshan coal with 40% better coking coals to produce blast furnace coke.

It is found also that medium grade bitumites§ (Bm) blend better with low grade bitumites (Bl) than the high grade bitumites (Bh).

INTRODUCTION.

Most of the coking coals in China are situated in the northern part of this country. Though there are coal fields in the central and southern part, their characters are not quite known and therefore the suitability of these coals for the manufacture of blast furnace coke has to be carefully studied.

The success of the proposed iron and steel works on the lower Yangtze using the iron deposits in that district[1] as recently planned by the Government depends largely on the availability of cheap and good coke produced from coals located not too far away.

A good blast furnace coke together with cheap transportation are always essential to an iron and steel industry. To lower the first cost in transportation, a coal field close to the iron deposit is undoubtedly desirable. Naturally the coal fields of Chinhsien and Hsuancheng in Anhui[2] producing a medium bituminous coal came first into consideration, but their high content in ash

§ For the significance of these names, see W.H. Wong: Classification of Chinese coals, Bull. Geol. Surv. China, No. 8, 1926.

and sulphur together with insufficient reserve as maintained by geologists should place this field at best as a secondary source of supply. The coking properties of the Liehshan and Luichiakou coal fields of northern Anhui[3] are yet little known and proper investigation is now under way for their evaluation.

The Shengkengshan coal field[4] is easy to reach and situated not far from the proposed plant site somewhere near Pukow. The coal is of a low grade bitumite (Bm)[5] and possesses a medium variety of coking quality, ranging from moderate coking to non-coking. Using 100% of this coal for coke manufacture seems to be impossible, but coal blends with a better coking coal will naturally improve its quality.

The Chunghsing coal of Ihsien, south Shantung, has long been regarded as one of the best coking coals in China. It possesses not only high agglutinating power, but also is low[6] in ash. The coke from this coal produced in native bee-hive ovens has been known for its excellent quality. The mine is not far from Shengkengshan and therefore the two coals can be easily brought together. Coal from Kailan mines also proves to be of high agglutinating power; the chief drawback in this coal is its high ash content. If the special washed coal is used, the ash content may be considerably lowered. Though it is far away from lower Yangtze, its location can afford a cheap transportation by water route.

It was therefore suggested that blending Shengkengshan coal with a part of Chunghsing or Kailan coal in certain suitable proportion might result in a good mixed coal for blast furnace coke. If it is possible, though at present it still needs further confirmation by large scale test, to produce a desirable metallurgical coke in this manner, the rather inferior coking coals from Shengkengshan can be utilized for useful purposes, and on the other hand, there will be a great saving of excellent coking coal from other mines. Excellent coking coals in China are rather limited, so economical conservation should be considered.

Studies along this line have been made for sometime and the following is an account of the work which has been done so far.

The study of this subject was carried out in three different parts, namely, (1) Agglutinating test, (2) Low temperature carbonization assay and (3) Horizontal gas retort carbonization. The procedures and observations of the experiments are described in the following.

TEST FOR MEASURING THE AGGLUTINATING POWER OF COAL.

Since 1870 Richtets[6], 1895 Campredon[7] proposed to test the agglutinating power of coal, many observers have thoroughly investigated on this subject. A good summary on this subject is fully given by S. M. Marshall, and B. M. Bird[8] so that it is unnecessary to review them again. In general the tests involve "the carbonization under standard conditions of a small sample of carefully prepared coal, either alone or mixed with inert material, and some tests of the resulting coke buttons which serve to indicate the agglutinating value of the coal"[9]; the inert material used being either quartz, electrode carbon or coke.

After careful consideration of the used methods and availability of apparatus and materials, the following procedure is choosen for the agglutinating test on the coals and coal blends used for this study.

Inert material employed in the test being a high temperature coke with a maximum of 2.2% volatile matter. This type of coke is readily available on the market. Large quantities are purchased for storage to minimize the variation of coke obtained at different times. The cokes are grounded to pass 40 mesh (Tyler Standard) and retain on 60 mesh sieve. Above 40 and under 60 should be discarded. Samples are carefully taken and analysed.

A part of the coal samples are sampled and supplied by the mines. They have been securely packed in cans and boxes during transport. Another batch of samples are collected by Mr. Y. S. Chi of our Survey. They are packed in sacks of about 200 lbs each. Owing to heavy rain in the summer season, these samples have been considerably weathered. All the samples are air dried at room temperature and pulverized to pass 60 mesh sieve in Braun Pulverizer and stored in glass bottles with a metal clamp lid. Proximate analysis of coal is then made with their respective percentages shown in the attached tables (I and II). Some proximate analyses of the same type of coal supplied by other laboratories are also included.

The proportion of 1:6.6 that is 1 part of coal to 6.6 parts of coke is adopted after a series of experiments. This ratio of coal and coke will produce a loose button which crumbles to touch by fingers when made from a very feebly coking coal. The total weight of the sample button before carbonization weighs 11.5 grams (10 grams coke and 1.5 gram coal). 20 samples of coke of 10 grams each are weighed out and then another set of 20 samples of coal of 1.5 gram each. One sample of coke and another of coal are carefully and intimately mixed. The mixture is then transferred into a 30 cc crucible and a weight of 5 kilograms is applied for 1 minute after leveling of the surface. The empty space in the crucible is filled with coke of 20-40 mesh sieve.

The furnace is electrically heated and in the form of a muffle. The furnace is heated to 960°C before the crucibles are put in. The time of carbonization is set at 10 minutes. The temperature in the furnace should reach 950°C within 5 minutes after the crucibles are put in. The crucibles are laid aside for about 20 hours before crushing. The weighing and mixing of the buttons are usually performed in the morning and the carbonization in the afternoon. The next morning, the buttons are crushed for estimating the agglutinating value (Plate III).

The testing is made on a very simple apparatus shown in the figure (Plate II). The value is ascertained by the number of times the carbonized button can stand the force of a metallic plate weighing 140 grams dropping from a distance of 6 cm. This test is not at all satisfactory for many reasons and therefore changes are now being made. It is intended to apply an increasingly steady force by using lead shots or iron shots for crushing such as used in testing cement briquets. This should give more readable values than the number of blows as now indicated.

A comparison of the coking values of Table I and II, there seems that the samples, except No. 587, collected by Y. S. Chi have in general a lower value than those supplied by the mines. The values for blends are still lower, this is mainly due to the difference of Chunghsing coal used. As I have mentioned, the tremendous amount of rain in the summer 1932 should have played an important part in the weathering of coal. Since the coal samples were stored in sacks and considerable time was required during the transport, and besides this batch of sample weighed over two tons, it was very hard to store them indoors at the time of heavy rainfall. Consequently more weathering has occurred.

With the exception of 2nd seam South, the ash percentage of all the new samples are much higher, but its difference does not affect the agglutinating value very much. A striking difference is noted between the samples from Tatung Mining Co. Of the former samples collected by the mines had no sign of coking at all while the new sample (average sample) shows a little better than all the other ones.

LOW TEMPERATURE ASSAY.

Gray and King of the British Fuel Research Board[10] have devised a laboratory method for evaluating the approximate by-products of coal. This method has been recognized as a good test for indicating the coking character of coal[11]. In lack of apparatus for this test, a still smaller coal assay method is devised and used. The general principle is altogether the same as the 20 gram assay.

This method consists of a pyrex tube of 20 cm long 2.5 cm diameter holding a coal sample of 10 grams. The tar collector is a part of U-tube. The gas-washing tube is simply made from two cheap type pipettes bending in such a manner as to be easily connected to the tar collector on one end and gas holder on the other. A large bottle of 3-liter capacity is employed as the gas holder. The gas entering at the top displaces the water which is saturated with coal gas from previous tests. The displaced water flows to a leveling bottle of 2 liter capacity.

The operation is very simple. A ten gram sample (dried at 105°C) occupies the lower three-fifth of the tube and is connected to the tar collector which is dry and empty. Eight cc of normal sulphuric acid is charged into the ammonia absorption tube for the absorption of ammonia and other basic gaseous compound that are coming through. This is connected next to the tar collector.

The pyrex tube filled with the prepared sample is inserted partly into an electric tube furnace which is heated to 300°C beforehand after the current is raised. The temperature is gradually increased. The rate of heating is so arranged that at the end of 1 hour, the furnace attains a temperature of 600°C, which is measured by a base metal thermocouple. This temperature 600°C is maintained for another hour or more until the gas evolution is practically ceased. Usually one hour at 600°C is sufficient for complete gas evolution. The total time of carbonization is 2 hours and 10 minutes.

The volume of gas can be easily measured by the calibrated scale on the bottle. The total volume of gas is collected to 15°C as saturated gas. The tar, liquor and gas are not carefully estimated since they have no direct connection on the whole experiment.

The general arrangement of the apparatus and also some of the cokes formed are shown in accompanied photographs (Plate, I 2, IV, V). A description of the resulting low temperature coke and a comparison of the coke and the coke button from volatile matter determination are fully given in Table III.

CARBONIZATION IN HORIZONTAL GAS RETORT.

After initial testings in the methods described, a decision was henceforth made that a larger sample of blends should be used for testing their suitability for coke manufacture. My colleague, Mr. Y. S. Chi, was so kind to have collected nine new samples about 400 lbs each on a special trip. It was quite unfortunate that during this year heavy rainfall in North China has resulted in washing out all the fine particles from the coal in the sacks.

Preliminary tests of these samples showed little difference with the old ones inspite of the fact that they are considerably weathered. Subsequently they were all ground to pass 1/4" in Braun laboratory crusher and intimately mixed by hand with Chunghsing dust in the proportion of 4 to 6, that is, 40% Chunghsing and 60% Shengkengshan. The sieve analysis of two samples after crushing is shown below.

Sample	Chunghsing	Shengkengshan
on 1/4"	77%	25%
on 10 mesh	16%	40%
under 10 mesh	7%	35%

Two lean blends with 70% Shengkengshan were also mixed for testing.

The test was made at the Horizontal gas retort of Peiping Union Medical College. The retort is made of fire brick and four in a bench. By not disturbing the gas generation of P.U.M.C., by-product estimation was abandoned entirely and only coke was concerned. It took 8 hours for heating a charge of 300 lbs at a maximum temperature of 900°C. The charging and discharging were made by hand.

Owing to many difficulties the conditions for carbonization are differed from those of standard carbonization. Therefore the retorts were not fully charged, temperature was lower than usual and the time was limited only to eight hours.

Nevertheless, the tests were made, and slightly shiny surfaced cokes (Plate VII) were produced. The coke appears quite hard and difficult to break. Shatter and tumbler tests are unavailable for testing the coke strength here; only the analysis is performed. The results are shown in Table IV. Examining the coke by Rose Method[12], there are numerous black and very hard infusible particles cemented in the cokes of fairly porous structure (Plate $VIII_3$). Ash determination on these particles shows that they contain as high as 40% ash. Accordingly, they are the ash forming material and probably could be washed out if coal cleaning plant is provided.

In one sample, that is 40-60 mixture of Chunghsing and Tatung, the infusible particles are only present in small quantities. The structure of this sample is different from the rest and possesses a quite uniform cell structure (Plate VIII 1 & 2). But the surface remains dull as others, except it feels a little harder and more porous.

According to the observations on coke structure, it seems that the ash content has an important bearing on the porosity as well as the hardness of coke. In all cases, the smaller the ash content, the more porous is the structure.

DISCUSSION.

Both coals from Chunghsing and Kailan of the Bm type are taken as excellent coking coals in this country. And those of Tzuhsien and Liuhokou of the Bh type, as far as the native bee-hive oven tests have shown, are also of good coking quality. The chief difference between these two types of coal lies in the fact that the former two are highly swelling coking coal and the latter are only of moderate swelling. This can be shown very evidently by carbonizing the coals at 600°C in the carbonization test.

Furthermore, Shungkengshan coal (Bl type and poorly coking) blends with either Chunghsing or Kailan up to 50% showed still noticeable swelling in the carbonization test, while these blends of Tzuhsien and Liuhokou do not form quite shiny but loose coke at the temperature of 600°C. When the agglutinating test is applied, Tzuhsien and Liuhokou blends even at the amount of 60% coking coal showed little evidence of coking, and cracked very easily at the test. On the other hand, blends made of 30-40% Chunghsing or Kailan and 70-60% Shungkengshan medium coking coal shows considerable strength of agglutination and the values can be compared with those of 100% Tzuhsien and Liuhokou.

In evidence of these facts, the excessive swelling in coking coal proves to be not entirely necessary in the coke formation, but would be very useful in blending the poorly coking coals. The normal swelling coking coals such as Liuhokou and Tzuhsien are merely good for producing coke by itself and of no advantage for blending other coals. In other words, low volatile bituminous coking coals of the Bh type are only good for making coke alone while Bm coals or medium volatile bituminous coking coals are useful for blending purpose depending on their special property of excessive swelling. By this manner, that is, blending with a coking but non-swelling coal, the excessive swelling can be somehow eliminated with a result of having a normal swelling and good coking coal. Tests made with Kailan coal give very similar results which proves that either Kailan or Chunghsing coal might be used for the same purpose.

The general appearance of low temperature coke from 40% Chunghsing 60% Hwainan (2nd hole, 1st seam) of Shungkengshan is quite similar to that of Liuhokou (Plate VI) any even the agglutinating values are alike. Blends richer in Chunghsing (50% up) shows considerable swelling, giving a coke quite shiny, and can be easily crushed owing to the porosity of the coke. Blends with lower percentage in Chunghsing (20% down) give a mass of jet black color.

compact; little shiny in places, quite fissury and non-swelling. Chunghsing in 10% gives a coke of little difference to 0% Chunghsing or 100% Shungkengshan coal. Basing upon these evidences from the tests, one might say that the blends made of 40% Chunghsing, 60% Shungkengshan would produce a desirable coke for blast furnace. However, only large scale experiment in coke oven will definitely prove its suitability for metallurgical coke and assure the practical ratio for constituting the blend. This seems rather expensive for experimental purposes. Consequently, arrangement is made with Peking Union Medical College to use their gas retort for testing. This is, of course, not quite as satisfactorily as ovens, yet its indication will probably justify further experiments on full scale coke ovens.

Since Shungkengshan coals include a wide variation of coking quality in different regions and also in different seams, assurance should be obtained first as to whether that seam which proves to be promising under test is of considerable reserve, or other seams may prove to possess similar property and can be used along with it. Of the six samples (No. 483-488) differing in seams, supplied by the Hwainan Coal Mining Administration of Shungkengshan, the third seam of the 4th hole west in the south and 1st seam, probably also the 3rd seam of the 4th hole west in the north (designations according to original labels) are of the same general property as that of the 2nd hole 1st seam. This gives a more wide limit in the coal reserve that might possibly be blended with other coking coals of highly swelling nature in the ratio indicated. Low temperature assay and agglutinating value test show evident similarities between these three coals of the 4th hole west and that of the 2nd hole 1st seam. All these were made in the proportion of 40% Chunghsing 60% Shungkengshan.

Coals from Tatung Mining Company of Shungkengshan seem to be of inferior coking quality. Tests on the individual samples from different seams showed feebly coking quality, while of the average sample No. 432 has no sign of coking at all.

Among the samples collected by Mr. Y. S. Chi, the average sample of Tatung coal stood out as the best coking quality of the whole lot of Shungkengshan coals. Not only the agglutinating value is high, but also the general appearance of coke, hardness, porosity as well as the ash content are better than others. Probably the ash forming material such as shale and slate hinders the coking quality of the others. This is shown in the analysis, the higher the ash content, the lower the agglutinating number. It is therefore suggested, if these coals were washed, they might improve the coking quality of the coal a good deal. Float and Sink test will be applied to new samples to verify this point.

All the other samples are moderate coking, but none can be compared with that of Tatung both in the original coal and coal blends. Perhaps, the general characters of Shungkengshan coal are alike and the chief differences are mainly due to the percentage of ash content and the relative presence of durain and vitrain in the coal.

In the mean time, due to the difference of the samples collected at different times and also the wide variation of weathering conditions, due to difficulties in transporting the samples from one place to another (it took practically two months to transfer Mr. Chi's samples from the mine to Peiping); due to handicap in apparatus for crushing and mixing large quantities of coals, large scale experimental test at regular coke ovens (Chinghsing Coking Plant of Shihchiachuang, Hopei) as originally planned does not seem to be worthwhile. But, according to the tests so far made, there still lies a strong hope that Shungkengshan coal can be used for a more noble purpose after being mixed with better coking coals. This purpose is the production of blast furnace coke for iron and steel industry on lower Yangtze.

Hsuancheng and Chinghsien coals are quite promising for blast furnace coke as far as the samples have shown in the test. It seems that Hsuancheng coal has a higher agglutinating value than Chinghsien, but, one weathered sample showed no sign of coking at all. At any rate, these two fields are of little importance as their total reserves are not yet sure and these coals are generally too high in sulphur and ash. Their utilization must wait for further investigation.

SUMMARY.

a. Coal from different seams of different Shungkengshan coal mines collected at different times are not alike in their coking properties.

b. In the first batch of samples, 1st seam S. No. 2 hole and 3rd seam S, 1st seam N and 3rd seam N of 4th hole of Hwainan Mining Administration produce a coking coal of non-swelling nature but form compact and hard mass of coke.

c. 40% Chunghsing or Kailan coal used in blending the above four coals could produce a good coke comparable in shape and swellness with the coke produced from Liuhokou or Tzuhsien coals alone.

d. Coals from Liuhokou and Tzuhsien are not good for blending but those of Kailan and Chunghsing are very good for blending poor coking coals because of their special property of excessive swelling.

e. Tatung coal of Shungkengshan was not investigated seam by seam. The average sample as tested can hardly form any coke even with the ratio of the blend increased to 60% coking coal, but a new sample showed a much better coking quality, even better than all the other samples from the same field. The new sample collected by Chi should be considered as the representative sample.

f. Tests in horizontal gas retort indicate that the new Tatung average sample mixed with 40% Chunghsing coking coal produces a quite desirable coke according to the general appearance.

g. Aside from inefficient transportation facilities and shortage of proper machanical appliance, a trial test on a large scale plant seems worthwhile.

h. Hsuancheng and Chinghsien coals look quite promising for the production of metallurgical coke except for their high ash and sulphur content. But this conclusion is based only on a few samples under test.

i. The medium grade bitumite (Bm) such as Chunghsing and Kailan coals are far better for blending purpose than high grade bitumite (Bh) from Liuhokou and Tzuhsien on account of the excessive swelling character.

ACKNOWLEDGEMENT.

The writer is indebted to Chief Engineer Alston of P.U.M.C. who helped in making the gas retort test and my colleague Mr. Y. S. Chi who made a special trip to Shungkengshan and carefully collected nine new samples for the test. Thanks are also due to Miss T. C. Hung who assisted in the coal analysis.

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TABLE I

Proximate Analysis and Agglutinating Values of Shungkengshan Coals and their Blends.

(Coals supplied by mines)

Lab. No.	Sample No.	Coal provenance	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating values (calories)	Agglutinating value
		Hwainan Coals							
483	1	west 4th hole 1st seam S	2.42	33.75	48.53	15.30	—	6577	crumbles
484	2	,, 2nd ,, S	1.74	33.47	39.63	25.16	—	5558	,,
485	3	,, 3rd ,, S	2.11	36.32	48.67	12.90	—	6713	2
486	4	,, 1st ,, N	2.05	39.60	48.54	9.81	—	6712	2
487	5	,, 3rd ,, N	2.15	40.35	48.35	9.15	—	6667	1
488	6	,, 4th ,, N	2.55	36.95	49.30	11.20	—	6765	1
433	7	2nd hole 1st seam S	1.45	36.62	50.41	11.52	0.54	6841	2
355	8	1st hole	2.49	37.32	51.61	8.58	0.90	7029	—
356	9	2nd hole	1.75	37.93	51.70	8.62	0.85	7083	—
357	10	4th hole	2.91	36.46	52.88	7.75	0.68	7252	—
	11	(1) Hwainan	3.30	32.59	50.91	13.20	1.26	6615	—
		Chunghsing, mixture,							
	12	90% 433, 10% 369	1.29	36.56	51.10	11.05	—	7004	2
	13	80% 433, 20% 369	1.14	36.07	52.37	10.42	—	7258	5
	14	70% 433, 30% 369	1.00	35.83	53.44	9.73	—	7247	4
	15	60% 433, 40% 369	0.84	35.46	54.60	9.09	—	7403	5
	16	50% 433, 50% 369	0.78	34.82	55.83	8.57	0.61	7501	5
	17	40% 433, 60% 369	0.61	33.89	57.69	7.81	—	7712	7
	18	90% 433, 10% 374	1.25	37.97	49.18	11.60	—	6769	2
	19	80% 433, 20% 374	1.19	37.47	49.70	11.64	—	6771	2
	20	70% 433, 30% 374	1.13	37.20	49.85	11.82	—	6765	3
	21	60% 433, 40% 374	1.01	36.76	50.31	11.92	—	6745	5
	22	50% 433, 50% 374	0.93	36.28	50.18	12.01	—	6906	5
	23	40% 433, 60% 374	0.73	35.26	54.89	12.12	—	7074	7
	24	70% 433, 30% 365	1.28	31.52	54.33	12.87	—	7227	3
	25	60% 433, 40% 365	1.24	30.54	54.81	13.31	—	7171	2
	26	50% 433, 50% 365	1.20	30.56	54.79	13.45	—	7272	2
	27	40% 433, 60% 365	1.14	30.26	54.95	13.65	—	7248	3
	28	70% 433, 30% 319	1.15	31.25	57.03	10.57	—	7633	2
	29	60% 433, 40% 319	1.05	30.40	58.37	10.18	—	7642	2
	30	50% 433, 50% 319	0.98	28.92	60.10	10.00	—	7703	2
	31	40% 433, 50% 319	0.84	27.21	62.45	9.50	—	7780	2
		Chunghsing, Mixture,							
	32	60% 483, 40% 369							1
	33	60% 484, 40% 369							2
	34	60% 485. 40% 369							5
	35	60% 486, 40% 369							4
	36	60% 487, 40% 369							3
	37	60% 488, 40% 369							3
342	38	Tatung, 1st seam	2 70	41 85	42 68	12.77	0.62	6200	—
343	39	,, 2nd ,,	3.12	36.54	54.14	6.20	0.60	7027	—
344	40	,, 2nd ,,	2.94	37.33	52.73	7.10	0.74	7108	—
345	41	,, 3rd ,,	2.43	36.61	54.80	6.16	1.10	6990	—
346	42	,, 4th ,,	2.96	35.85	50.77	10.42	0.75	6884	—
347	43	,, 8th ,,	1.76	28.93	45.80	23.51	1.50	5857	—
432	44	,, average	1.73	33.49	42.78	22.00	—	5954	crumbles
	45	(1) ,, 1st ,,	2.24	31.42	48.54	17.80	0.73	5901	—
	46	(1) ,, 4th ,,	1.17	36.87	45.46	16.50	1.10	6280	—
	47	(1) ,, 5th ,,	0.70	37.74	50.67	10.80	0.74	5784	—
	48	(2) ,,	3.56	32.27	44.59	19.58	1.21	6722	—
447	49	Hsuanch'eng, Anhui.	0.25	30.20	44.48	25.07	6.37	6063	13
448	50	,, ,,	0.10	33.34	46.68	19.88	4.58	6394	12
449	51	Chinghsien, Anhui.	0.27	26.83	57.40	15.50	0.71	7307	9
450	52	,, ,,	0.20	28.22	58.06	13.06	0.71	7469	6
319	53	T'zuhsien, Hopei.	0.36	21.94	69.46	8.24	—	7975	5
365	54	Liuhokou, Honan.	1.07	23.68	60.05	15.20	—	7284	5
366	55	Chunghsing, Shangtung, (Tats'ao)	0.50	28.20	58.50	11.80	0.66	7504	—
367	56	Chunghsing, Shangtung, (Siaots'ao)	0.38	29.68	58.64	11.30	1.16	7627	—
368	57	Chunghsing, Shangtung, (not washed)	0.24	30.82	58.76	10.18	— / 0.95	7734	—
369	58	Chunghsing, Shangtung, (washed slack)	0.40	31.75	61.05	6.80	—	7990	21
374	59	Kailan, Hopei. (special washed)	0.42	31.98	55.20	12.40	—	7435	20
	60	60% 369 40% 432							2
	61	60% 374 40% ,,							2
	62	60% 365 40% ,,							2
	63	60% 319 40% ,,							1

1. Analysed by a Laboratory in Germany

2. Analysed by Chaiotung University, Shanghai

TABLE II.

Proximate Analysis and Agglutinating Values of Shungkengshan Coals and their Blends

(Samples collected by Y. S. Chi)

Lab. No.	Sample	Coal provenance	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Heating value	Agglutinating value
582	64	3rd seam N. 4th hole west (a) (c), Hwainan	1.77	32.51	51.32	14.40	0.60	6900	1
580	65	3rd seam N. 4th hole west (b), Hwainan	1.22	38.43	43.75	16 60	——	5907	2
579	66	1st seam N. 4th hole west (a), Hwainan.	1.64	37.06	47.79	13.51	0.39	6326	2
577	67	1st seam N. 4th hole west (b), Hwainan	1 40	38.34	46.06	14.20	——	6374	2
583	68	2nd seam S. 4th hole west, Hwainan	1.70	30.88	52.77	14.65	1.83	6865	2
578	69	3rd seam S. 4th hole west (a). Hwainan	1.60	32.32	45.38	20.70	——	6157	crumble
581	70	3rd seam S. 4th hole west (b), Hwainan	2.15	36.13	39.77	21.95	2.29	5479	crumble
584	71	Mixed coals from 2nd seam S. & 3rd seam N. 4th hole W., Hwainan	1.87	30.46	51.91	15.76	0.87	6815	1
585	72	Mixed coals from 3rd seam S & 3rd seam N. 4th hole W., Hwainan	2.04	32.58	48.59	16.79	1.11	6470	2
586	73	3rd seam S. 2nd hole E.. Hwainan	2.20	31.10	52.00	14.70	0 85	6920	1
587	74	Tatung average.	1.49	33.03	52.20	13.28	0.66	7011	3
596	75	Chunghsing dust.	0.80	30.42	55.43	12.35	1.71	7570	19
		Chunghsing Mixtures							
	76	40% 596 60% 587	1.19	32.91	53.14	12.76	——	7140	4
	77	40% ,, 60% 586	1.10	30.52	53.06	15.32	——	7331	3
	78	40% 596 60% 585	1.40	31.93	51.47	15.20	——	6921	2
	79	40% ,, 60% 584	1.87	30.46	51 91	15.76	——	6765	1
	80	40% ,, 60% 578	1.57	30.01	50.97	17.45	——	6675	1
	81	30% ,, 70% 581	2.12	32.44	50.94	14.50	——	6821	1
	82	40% ,, 60% 583	1.83	30.05	55.86	12.26	——	7365	2
	83	40% ,, 60% 577	1.37	37.13	48.44	13.06	——	6610	4
	84	30% ,, 70% 579	1.32	34.15	49.46	15.07	——	6700	4
	85	40% ,, 60% 580	0.61	30.56	55.78	13.05	——	7394	4
	86	40% ,, 60% 582	1.87	30.46	51.91	15.76	——	6806	2

TABLE III.

Comparison of General Appearances of Coke Button and Low Temperature Coke.

(Coal supplied by mines)

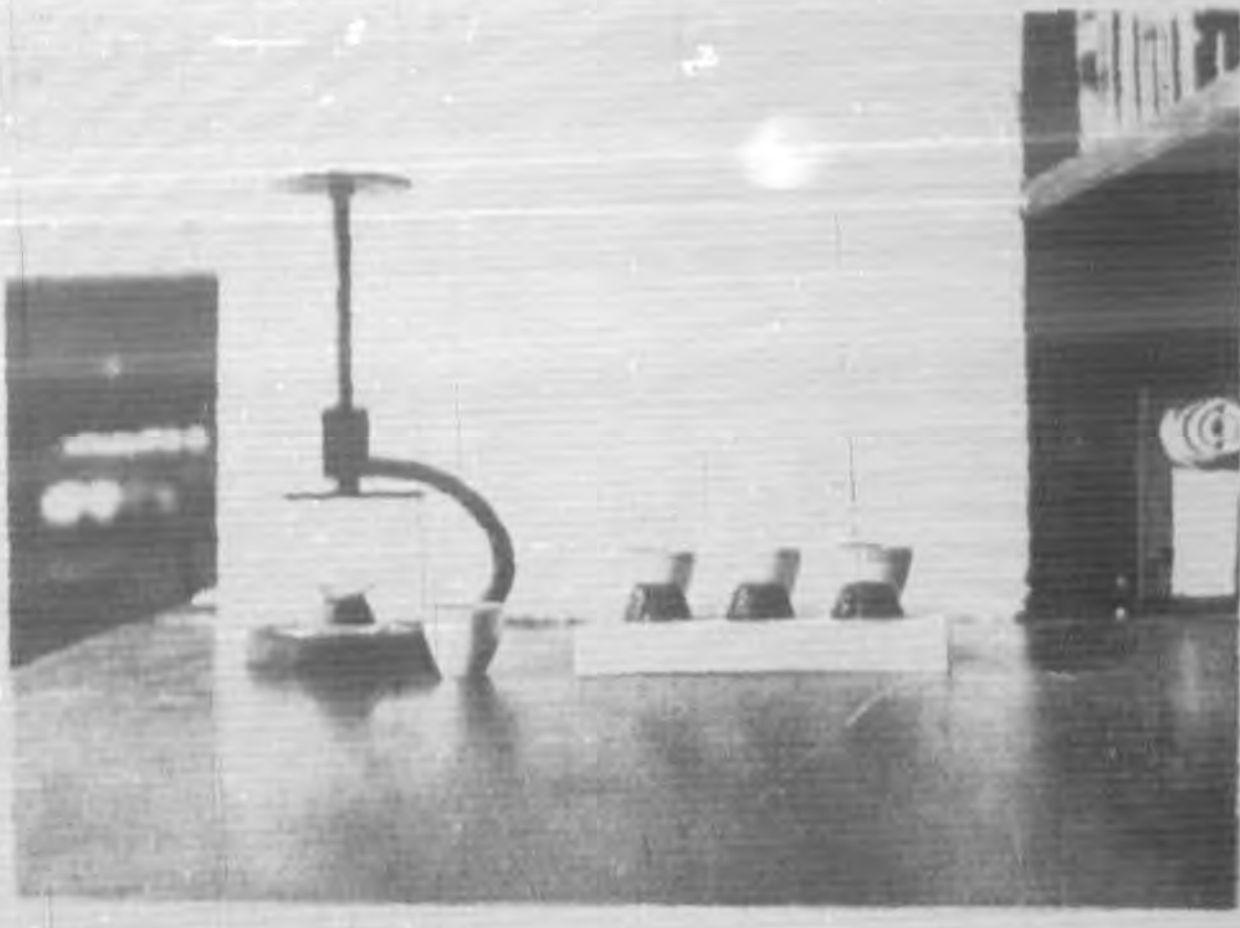
Lab. No.	Coal Provenance	Appearance of coke Button	Appearance of Low Temperature coke at 600°C
483	Hwainan Coal Mine, Shungkengshan, Anhui, 4th hole, west 1st seam S.	Dull grey-black, very, slight surface fusion. No swelling.	Dull black, coherent very fragile, no swelling, little powder,
484	Hwainan Coal Mine, Shungkengshan, Anhui, 4th hole, west 2nd seam S.	Grey, slight surface fusion, very slightly swollen.	Dull black, coherent, very fragile; no swelling, no powder.
485	Hwainan Coal Mine, Shungkengshan, Anhui, 4th hole west 3rd seam S.	Steel grey, with granular and partly fused surface, slightly swollen.	Grey black, lustrous in places, hand and compact mass, no swelling.
486	Hwainan Coal Mine, Shungkengshan, Anhui, 4th hole, west 1st seam N.	Grey, partly fused surface, swollen.	Grey black, lustrous in places, very compact, fissurous, no swelling.
487	Hwainan Coal Mine, Shungkengshan, Anhui, 4th hole, west 3rd seam N.	Dull grey, slight surface fusion, practically no swelling.	Grey black, compact & fissurous, no swelling.
488	Hwainan Coal Mine, Shungkengshan, Anhui, 4th hole, west 4th seam N.	Dull grey-black, very slight surface fusion practically no swelling.	Dull black, coherent, very fragile, no swelling, little powder.
433	Hwainan Coal Mine, Shungkengshan, Anhui, 2nd hole, 1st seam S.	Steel grey, with granular and partly fused surface, slightly swollen.	Grey black, lustrous in places, hard but fissurous, no swelling.
432	Tatung Coal Mine, Shungkengshen, Anhui, average sample.	Black, loosely coherent, slight swelling.	Black powder mostly, little particles loosely coherent.
447	Shuitung Kuankuon, Tawangts'un, Hsuanch'eng, Anhui.	Steel grey, lustrous, fused furface, considerably swollen.	Grey black, strong lustre, considerably swollen.
448	Shuitung Kuankuon, Tawangts'un, Hsuanch'eng, Anhui.	Similar to 447.	Same as 447
449	Huamit'ang, Ching Hsien, Anhui.	Similar to 447.	Grey black, strong lustre swollen.
450	Yenkungt'ang, Ching Hsien, Anhui.	Similar to 447.	Same as 449.
319	Yili Company, Hsitso, T'zuhsien, Hopei, Top coal.	Silver grey, strong lustre, fused surface, swollen.	Grey black, lustrous, fairly hard but porous, swollen.
365	Liuhokou, Honan.	Steel grey, lustrous, fused surface and swollen	Grey black, lustrous, hard and swollen.
369	Chunghsing Company, Shantung, washed slack.	Silver grey, strong lustre, fused surface, considerably swollen.	Lustrous, much swollen and with hard porous structure.
374	Kailan Mining Co., Kaiping, Hopei special washed slack.	Same as 369, more swollen.	Similar to 369 with still porous structure.
A	60% 369, 40% 433	Grey black, lustrous, fused surface and swollen.	Lustrous in places, much swollen and with hard porous structure.
B	50% 369 50% 433	Grey black, lustrous, fused surface swollen.	Lustrous, hard, swollen porous.
C	40% 369 60% 433	Similar to B but not so swollen.	Similar to 365 but more lustrous.
D	30% 369 70% 433	Similar to C, but less swollen	Grey black, lustrous in places fissurous, little swollen.
E	20% 369 80% 433	Similar to D, little swollen.	Grey black, lustrous in places, fissurous, no swelling.

TABLE IV.

Analysis of Cokes produced in Gas Retort

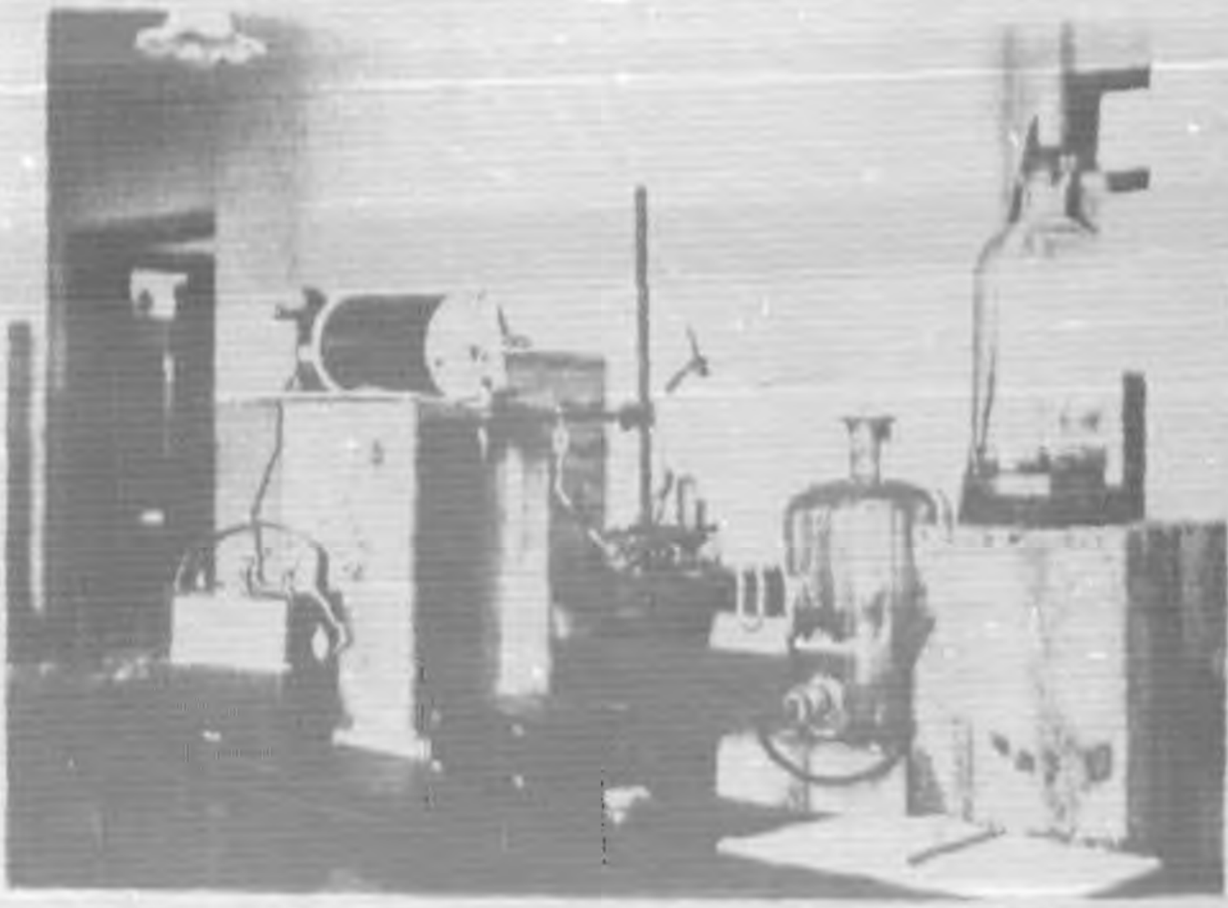
Lab. No.	Samples	Moisture	Volative matter	Fixed carbon	Ash
1	40% 596[1] 60% 587[2]	1.45	2.37	78.01	18.17
2	40% 596 60% 586[3]	0.95	6.07	76.53	16.45
3	40% 596 60% 585	1.09	4.56	72.94	21.41
4	40% 596 60% 584	1.70	3.72	76.03	18.55
5	40% 596 60% 578	2.15	2.68	76.67	18.50
6	30% 596 70% 581	1.94	4.38	76.02	17.66
7	40% 596 60% 583	2.05	3.95	74.25	19.75
8	40% 596 60% 577	0.48	6.74	75.51	17.27
9	30% 596 70% 579	1.69	2.46	75.71	20.14
10	40% 596 60% 580	1.37	3.20	74.86	20.57
11	40% 596 60% 582	1.14	2.14	77.65	18.07

1. Chunghsing dust.
2. Tatung average sample collected by Chi.
3. All other samples from Hwainan, Shungkengshan collected by Chi.



1

Testing apparatus for Agglutinating Value of Coal showing crucibles used in carbonization and the button under test as well as the crushed buttons. Note the cracks.



2

An assembly of apparatus for the Low Temperature Carbonization Test showing the electric tube furnace, tar collector, ammonia absorber, gas holder, leveling bottle, thermo-couple, pyrometer and ammeter.

Comparison between Coke Buttons of Coal and Coal Blends resulting from Volatile Matter Determinations.

First Series

1 2 3 4 5

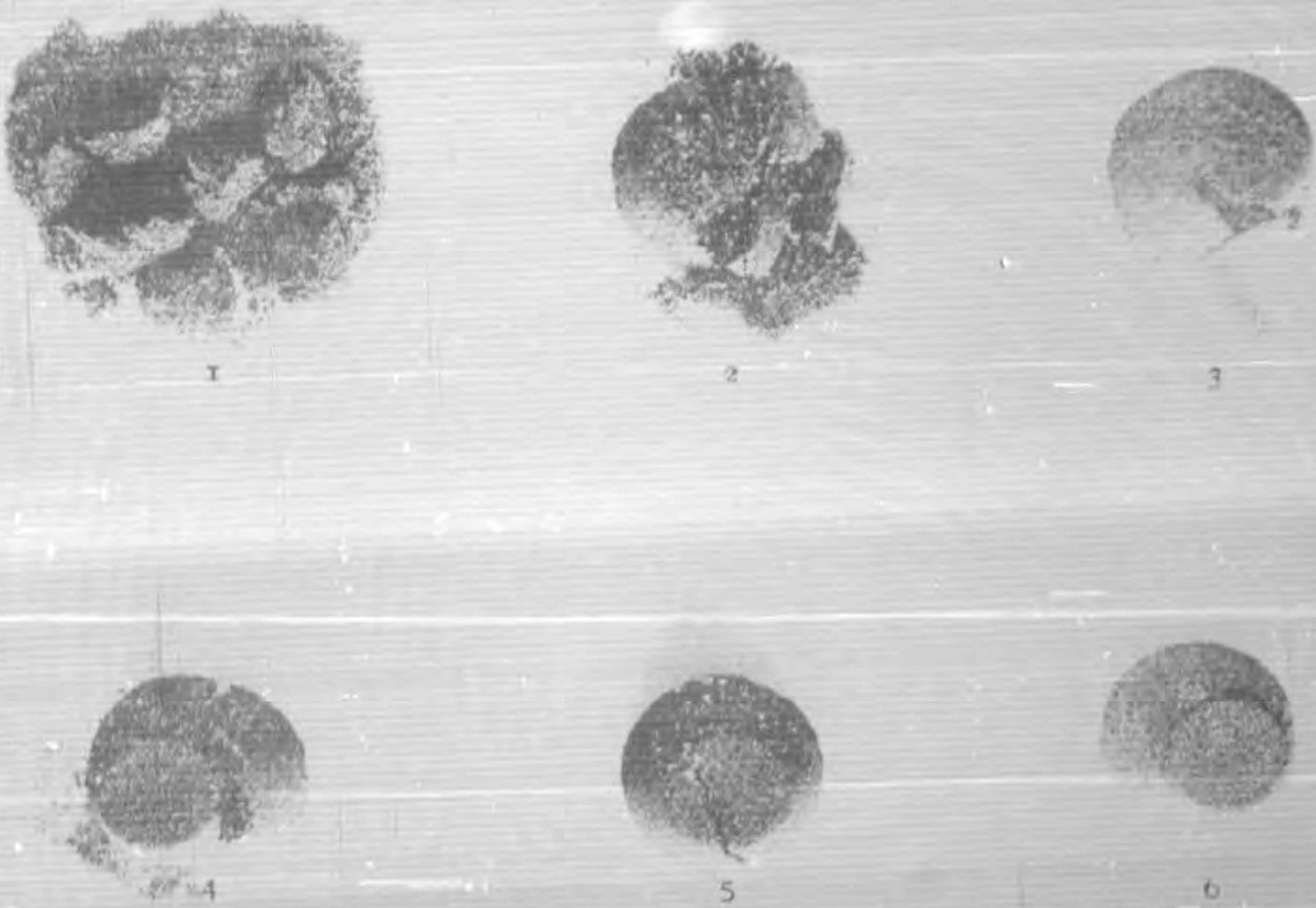
Second Series

1 2 3 4 5

First Series: (1) 100% Chunghsing, (2) 60% Chunghsing, 40% Hwainan, (3) 50% Chunghsing, 50% Hwainan, (4) 40% Chunghsing, 60% Hwainan, and (5) 30% Chunghsing, 70% Hwainan. Note the excessive swelling of Chunghsing Coal and the gradual decrease in swelling as the amount of Hwainan coal increases.

Secondary Series: (1) 100% Kailan, (2) 60% Kailan, 40% Hwainan, (3) 50% Kailan, 50% Hwainan, (4) 40% Kailan, 60% Hwainan and (5) 30% Kailan, 70% Hwainan. It seems that the Kailan coal gives more lustre than Chunghsing coal, otherwise, the difference is only slight.

Agglutinating Value Test Buttons.



1.—Shungkengshan coal (100%)
2.—Shungkengshan coal (55%), Chunghsin coal (45%)
3.—Shungkengshan coal (50%), Chunghsin coal (50%)
4.—Shungkengshan coal (45%), Chunghsin coal (55%)
5.—Shungkengshan coal (40%), Chunghsin coal (60%)
6.—Chunghsin coal (100%)

Note the difference in shape between the coking characters of 100% coals and their blends.

Low Temperature Coke Buttons from Different Hwainan Coal Seams produced in L. T. C. Test (Coal supplied by mines)

1 2 3 4 5 6

1.—1st seam S. 4th Hole West, loosely coherent mass and slightly swollen.

2.—2nd seam S. 4th Hole West, similar to 1.

3.—3rd seam S. 4th Hole West, hard and compact coke little swollen and surface fusion. This is perhaps the best coking coal among all the Hwainan coals tested.

4.—1st seam N. 4th Hole West, hard and compact coke slightly swollen and very little fused surface.

5.—3rd seam N. 4th Hole West, hard and compact coke quite fissury, little fused surface, very similar to the 2nd seam S. No. 2 Hole.

6.—4th seam N. 4th Hole West, loosely coherent mass but stronger than No. 1 and 2, slightly swollen and very little fused surface.

Low Temperature Coke Buttons from different proportions of Chunghsing and Hwainan, Shungkengshan coals.

1 2 3 4 5

1.—60% Chunghsing (washed coal) 40% Hwainan (1st seam S No. 2 hole.) considerably swollen with hard porous structure, quite lustrous.

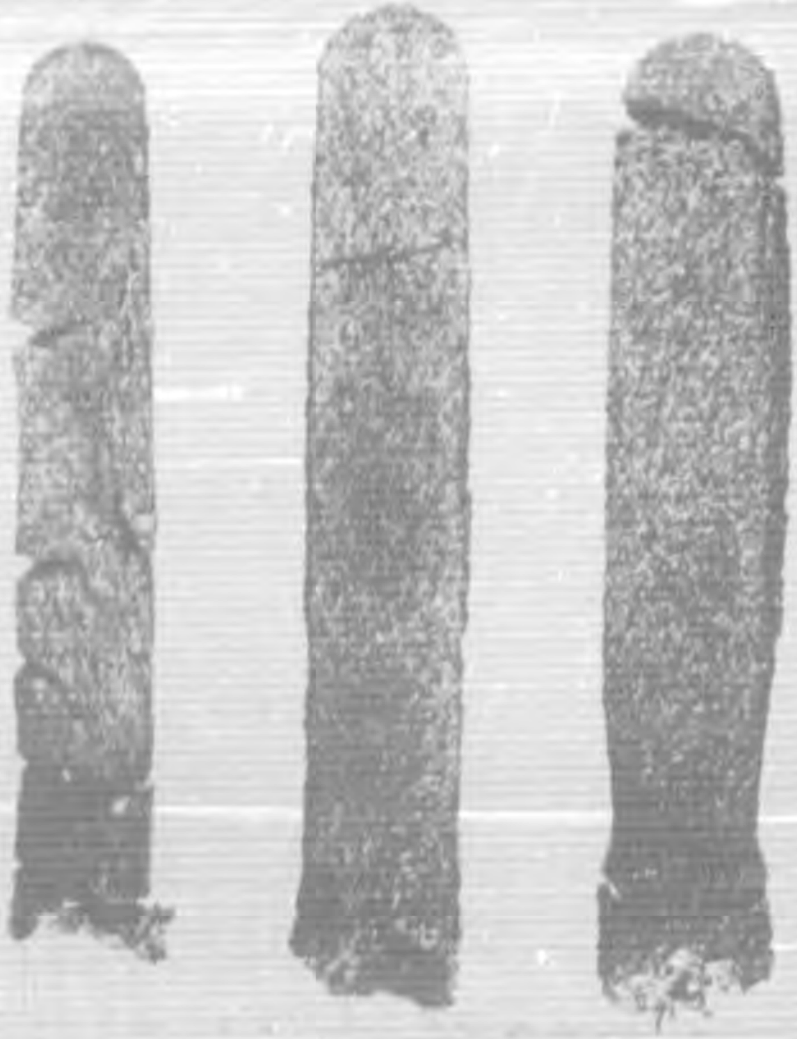
2.—50-50 Blend of Chunghsing and Hwainan, much swollen with hard and porous structure, Lustrous in places.

3.—40% Chunghsing and 60% Hwainan, much swollen with a very uniform hard and porous structure. Lustrous in places. This structure is very similar to that of 100% Lu-ho-kou.

4.—30% Chunghsing and 70% Hwainan, little swollen, quite fissury but hard coke. Lustrous in places.

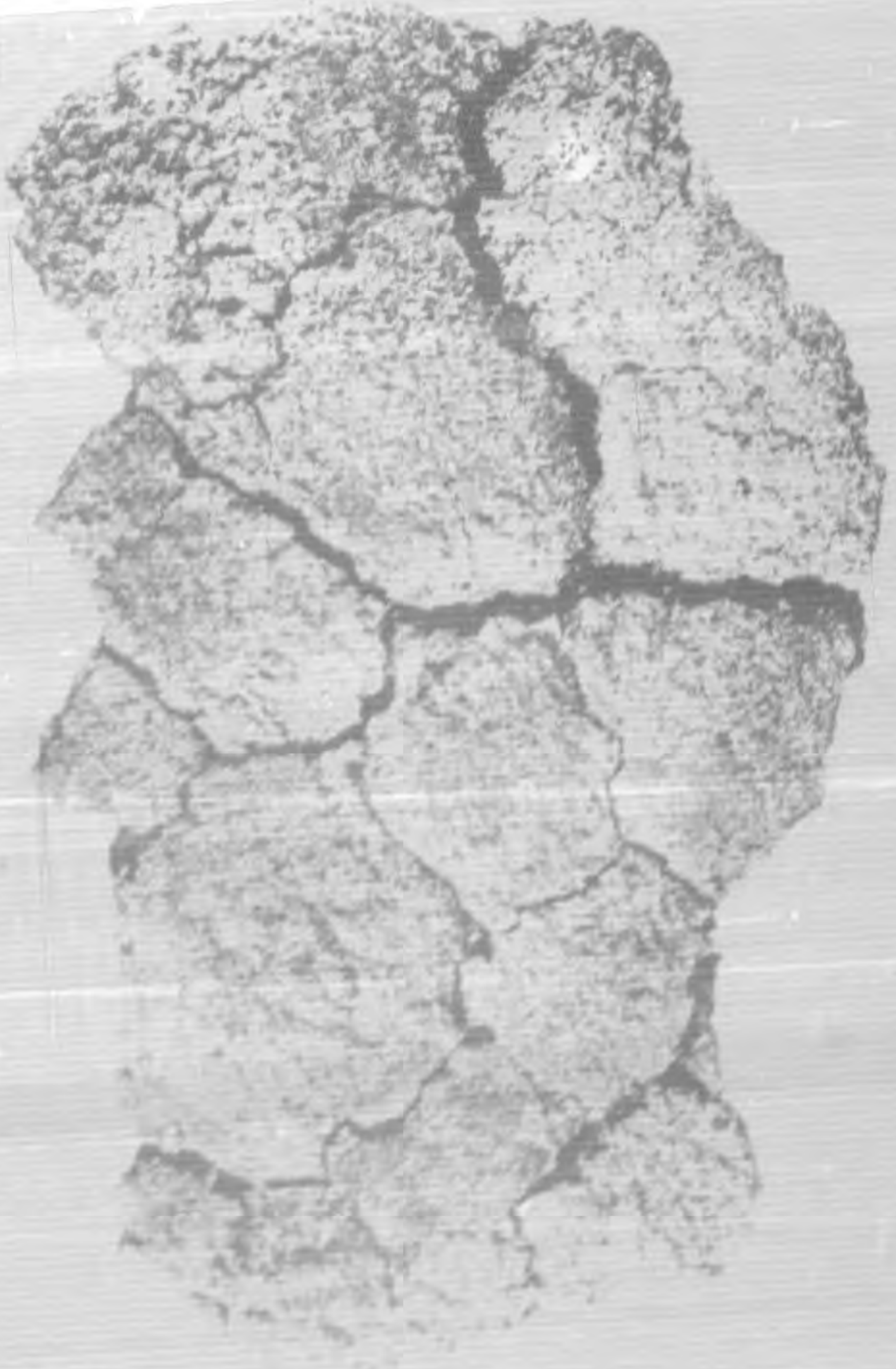
5.—20% Chunghsing and 80% Hwainan, slightly swollen, hard and compact coke with little lustre. Quite fissury and very similar to the original 100% Hwainan Coal.

Comparison between L. T. C. test cokes obtained.



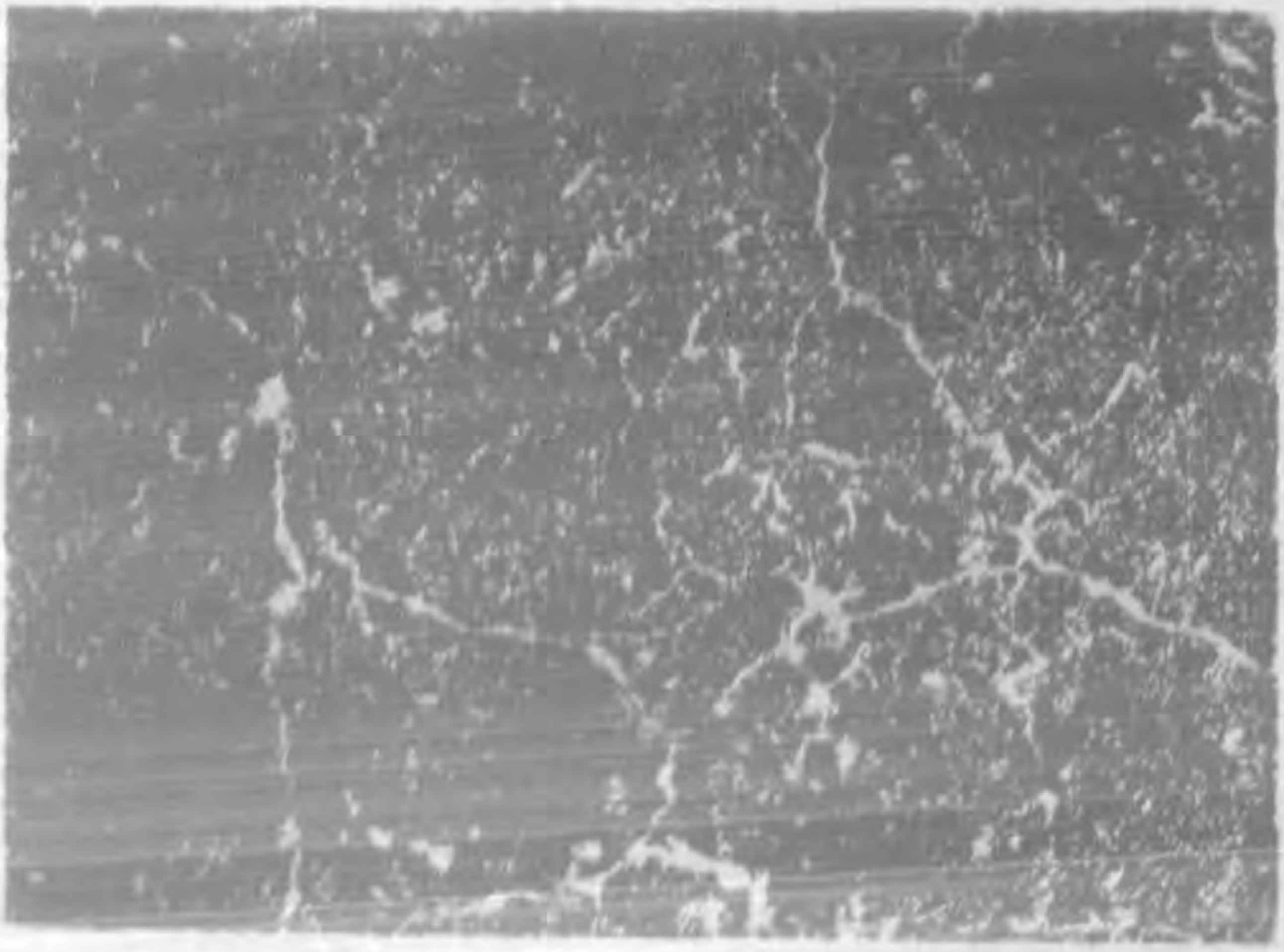
1 2 3

1. 100% Hwainan coal (1st seam S. 2nd Hole) Note its fissury structure. The coke as a whole is quite hard and compact, Little porosity. Surface fusion small and lustrous in places.
2. 60% Hwainan Coal and 40% Chunghsing coal, normally swollen, quite porous and hard. Fused surface and lustrous. Its cell structure is fairly uniform.
3. 100% Liuhokou coal, being known as a good coking coal. The general structure and the porosity appears very similar to No. 2 coal blend (60% Hwainan and 40% Chunghsing) except that of Liuhokou is little more swollen than the blend.



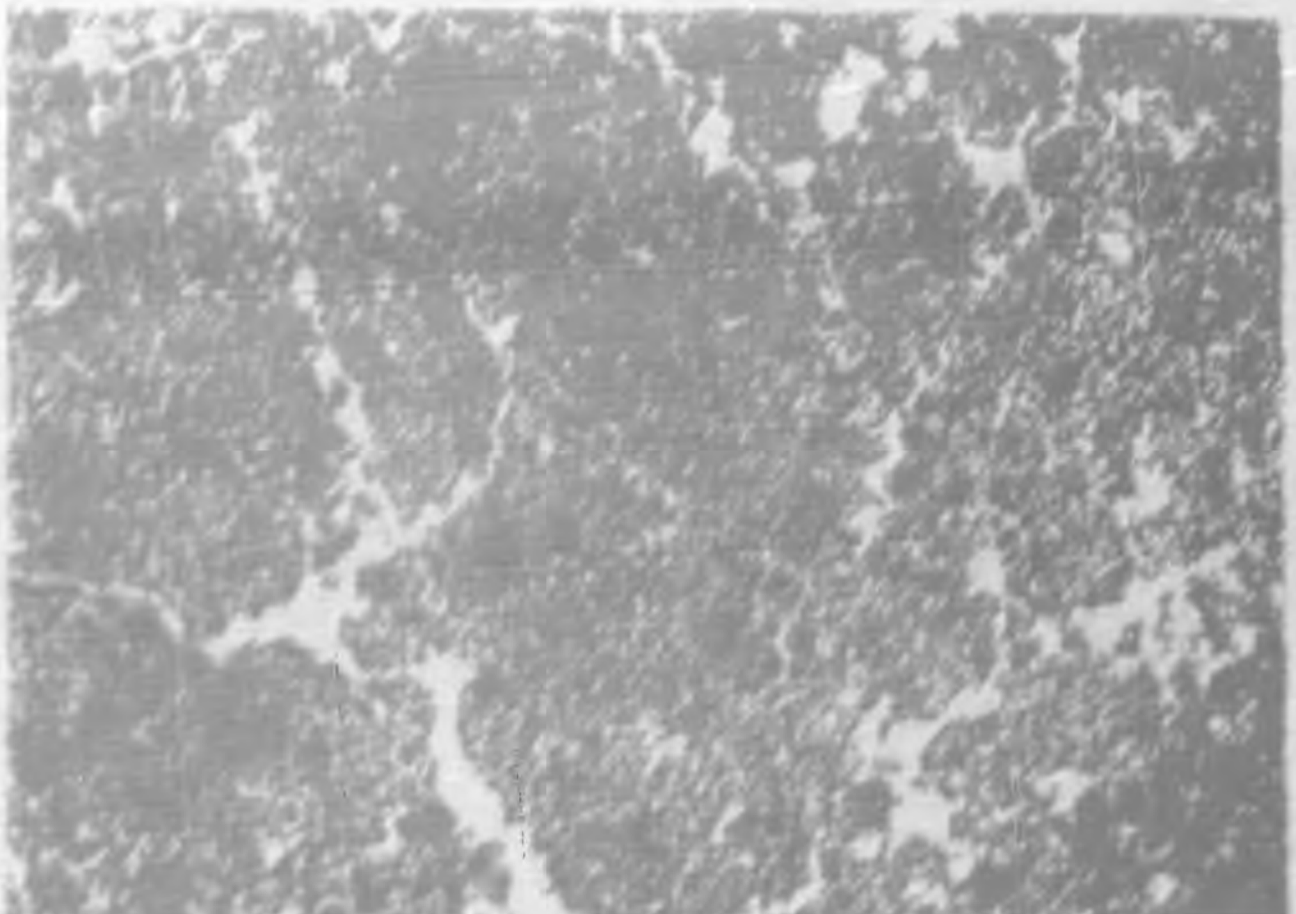
1

Gas retort coke from 31% Volatile matter and 12.[illegible]% Ash. "Coal Mixture" of 40% Chinchinhe coking coal and 60% Tatung poorly coking coal ½ × full size.



1

Retort coke from coal mixture of 40% Chunghsing coal and 60% Tatung coal of Shungkengshan. Cells filled with white composition. × 1.



2

Retort coke from coal mixture of 40% Chunghsing coal and 60% Hwainan (1st seam N, 4th hole west) of Shungkengshan cells filled with white composition. × 1. Notice the high ash (40%) black particles.

GEOLOGY OF OMEISHAN, SZECHUAN*

BY

H. C. T'AN AND C. Y. LEE

INTRODUCTION

After returning to Chengtu (成都) from Hsikang (西康) and the western border of Szechuan, where we made one year field work, in the early winter of 1930, we planned to take a further trip to Northwestern Szechuan, such as in the belt of Maohsien (茂縣) and Sungpanhsien (松潘縣), but it was told that the climate in winter did not permit the geological work. Thus we changed our plan and decided to go to the south instead of to the north. We left Chengtu on the 20th of November, through Chiating (嘉定) or Loshanhsien (樂山縣), and Chiachianghsien (夾江縣) and reached on Nov. 25, 1930 the Omei city** the name of which was derived from the famous mountain Omei (sometimes spelled Gnomei). Almost one month was spent in the surveying, and we left Omei on Dec. 28 for Chiating.

Location - Omeishan is one of four buddhist sacred mountains in China, they are Wutai in Shansi, Chiuhua in Anhui, Put'o in Chechiang and Omeishan itself in Szechuan. It is about 140 km. distant southwest from Chengtu, and situated at the latitude 29°30' N, longitude 103°20' E approximately. The elevation of the summit has been surveyed by us, being 3047 m above sea level and 2572 m above the Omei city, the altitude of which was taken as 475 m from the aneroid barometer and the boiling thermometer readings. (Fig. 1).

Previous works—Omeishan, besides being a center of pilgrimage, is also well-known for its beautiful scenery and by its conspicuous feature almost abruptly projecting on the border of the Szechuan basin and quite a fine Sum-

* This report went to press in Nov. 1932. Dr. Heim's paper "Tectonic study of Omeishan, Szechuan", sp. pub. Kwangtung and Kwangsi geol. Surv. No. XIII, came to our notice just in March, 1933 when the proofs of the present paper were already complete.

** Our visit in Omeishan was shortly followed again by Dr. Heim who went there in Feb. 1931. Similarly Dr. Heim's first visit was made two months later than our regretted colleague the late Mr. Chao in 1928. We regret that we had no opportunity of consulting Dr. Heim's manuscript before writing this report so as to avoid unnecessary repetition and confusion.

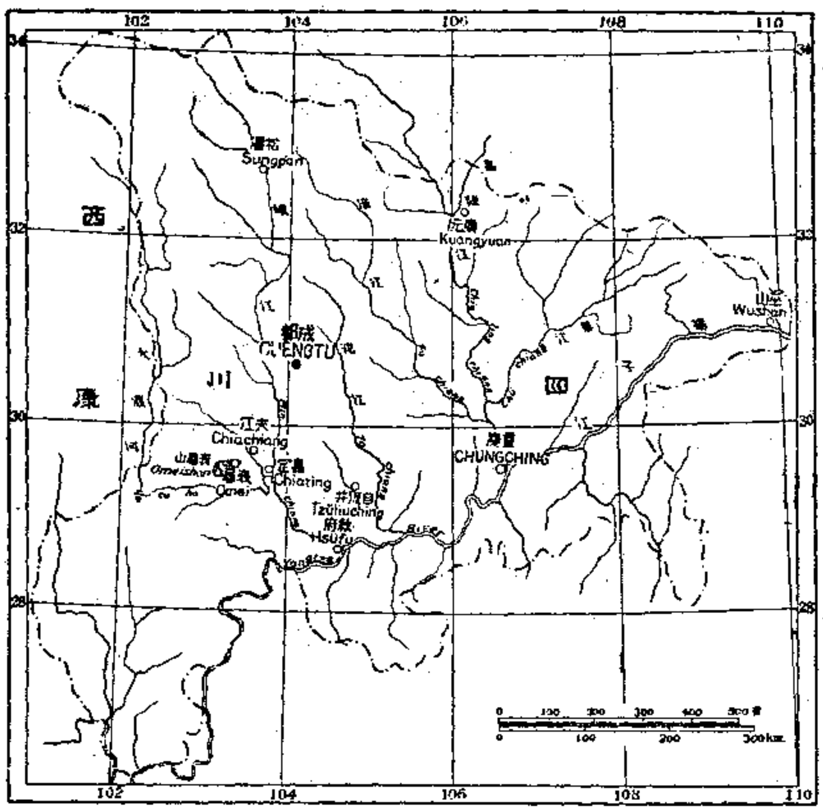


Fig. 1. Index map showing the location of the surveyed area in Omeishan.

mer resort for both travellers and investigators. E. H. Wilson, the American botanist, came here in 1903 for the botanical study, and recently there were some Chinese botanists who made big collections. The geology of Omeishan, however, was very little known. The first systematic study was made by the late Mr. Y. T. Chao[1], geologist to the National Geological Survey of China in the Summer of 1928. He spent only five days in the mountain, and has made clear all the essential details of the stratigraphy. The present paper is largely based on the foundation thus settled by him. Two months later Dr. A. Heim, a Swiss geologist, Professor at the Sunyatsen University of Canton, and geologist to the Geological Survey of Kwangtung and Kwangsi, came to Omeishan for several days. His contribution[2] chiefly

1. Yatseng T. Chao, Geological Notes in Szechuan, Bull. Geol. Soc. China, Vol. VIII, No. 2, 1929, p. 137-144.
2. Arnold Heim, The structure of sacred Omeishan, Szechuan. Bull. Geol. Soc. China, Vol. IX, No. 1, p. 59-74.

consists in the structural interpretation while the stratigraphy was essentially based on Mr. Chao's observation. Besides these, the geological atlas[1] of Szechuan on the scale of 1:200,000 by the Japanese geologist, Mr. Kobayashi, includes the Omeishan area. Unfortunately the geology and topography are somewhat misrepresented as has already been pointed out by Prof. Heim. Mr. C. L. Foster[2], Professor of the West China Union University, published some notes recording scattered observations on the geology of this area. His conclusion includes some wrong interpretations. So in regard to the geology of Omeishan the papers of the late Mr. Chao and Dr. Heim remain as the standard work. The present contribution consists mainly of the detailed mapping in topography and geology of this interesting area and the addition of rather minor details which have unavoidably escaped the rapid observation of Chao and Heim and some explanations which are tentatively offered as alternative to the views of the two preceding workers.

Method of Mapping—No modern map has been made until Mr. Chao published his geological sketch without however topographical contours. Our survey work was carried out with a set of theodolite, a set of plane-table, and stadia alidade for the topography, and aneroid and boiling thermometer for measuring elevations.

We started the work from the Omei city at the end of November, used the south gate as a datum and began to survey a map on the scale of 1:50,000 by using the stadia method and triangulation with the contour intervals of 100 m each.

GENERAL OBSERVATIONS

From Omei city to Fuhussŭ—Under the winter rain and fog, we slowly progressed on the muddy road, surveying about 5 km. in the first day. In the interval between the city and Paoningssŭ (保寧寺) it is free from hillocks, except some low mounds lying on the right side of the road, and comprising red clay and sandstone. The road itself is built on the surface of gravels in which the pebbles are mostly of quartzite with the cement made up of

1. G. Kobayashi and N. Horiuchi, Geological Research in China. Vol. I. pp. 293, 295. Atlas sheet 7.
2. C. L. Foster, Notes on Szechuan Geology, Journ. of the West China Border Research Society, Chengtu, Vol. 1. 1922-1923, p. 47-51.

yellow and orange-yellow clay. The pebbles and boulders are not uniform in size, ranging from few centimeters to 40 or 50 cm. in well rounded form. As the base of the gravels is not exposed, the thickness is hard to estimate, however a rough number of 30-40 m. may be guessed by comparing them with those south of Chiachiang.

Further southwest to the small village Lianghok'ou (兩河口) the outcrops of red clay and sandstone have been met with, dipping gently to northwest. From Lianghok'ou westward skirting along the hill foot, we climbed up a 20 m. high platform, on which the temple Paokuossŭ (報國寺) is situated. The moderate hillocks standing before the temple consist of red clay and sandstone dipping at 58° to NW while those behind it are composed of purple-red and greenish-gray sandstone and clay dipping at 70° more or less to west with the sequence of strata overturned. According to the position of the subdivisions of the Red Beds in Szechuan, the former belongs of the middle part or the Chiating formation (嘉定層) and the latter to the lower part, which is named the Tzuliuching formation (自流井層).

From Paokuossŭ going along the stream southwestward for 1 km we arrived at the temple of Fuhussŭ (伏虎寺) which is probably the largest one in Omeishan. The outcrops along the path are purple-red clay and greenish-gray and dark-gray sandstone dipping at 55° to S 75° W, the sandstone is characterized by an abundance of mica flakes. Below this sandstone occur the coal-bearing sandstones of the Hsiangchi[1] series of Jurassic age.

At the locality midway between Fuhussŭ and Paokuossŭ there is a hilly path leading to Shanchiossŭ (善覺寺), where the gray sandstone and dark shale of the Hsiangchi series are also exposed, dipping at 55°—74° to west by south. Behind Shanchiossŭ there is a hill with a rounded top named Fenghuangping, (鳳凰坪) amounting to 980 m in height. It is formed of the white-gray limestone which is partly thin-bedded and partly massive, underlying the sandstones of the Hsiangchi series, and dipping at 67° to east. The dipping angles gradually decrease westward and become almost horizontal near Huitengssŭ (慧燈寺). Some poorly preserved fossils of brachiopods and pelecypods have been collected from the upper part of the limestone.

1. J. S. Lee. Geology of Yangtze Gorge. Bull. Geol. Soc. China, Vol. III, No. 3-4. pp. 378, 379.

Both the fossil content and the stratigraphical position point to Upper Triassic age. It is designated by the name Chialingchiang limestone[1] because the same limestone is well developed in the lower Chialingchiang valley above Chungking.

From Fuhussŭ to Hsinkaissŭ—On the west of Fuhussŭ, the Hsiangchi sandstone and shale crop out within a width of about 500 m dipping reversely at 40-60 degrees to west, or S 80° W. Owing to the thorough weathering of the outcrops and covering of dense groves, the section can not be observed in detail. The debris on the slopes are of gray sandstones and dark-gray shales. There are no coal mines in the environs, this being probably due to the high inclination of strata and the thinning out of the coal seams. As shown however by the stratigraphical succession and the plant fossils collected at the locality near Fuhussŭ, the formation in this part is undoubtedly equivalent to the Hsiangchi series as we have found elsewhere. The plant fossils we collected have been studied by Mr. C. H. Pan, the list comprises the following:

Neocalamites hoerensis (Schimper)
Equisitites cf. *sarrani* Zeiller
Phyllotheca sp.
Cladophlebis cf. *kamenkensis* Thomas
Podozamites schenki Heer
Podozamites lanceolatus (Lind et Hutt.)

A little further westward below the Hsiangchi series is a thick sequence of gray limestone inter-bedded with yellowish-gray shale and calcareous shale, occasionally with an earthy appearance on the weathered surface, striking S 10° E. and dipping reversely at 58°-78° to west. It is the continuation of the limestone, which was found at Fenghuangp'ing on the north, and extends westward to Leiyinssŭ (雷音寺) where the beds of purple and green calcareous shales are intercalated. The total thickness amounts to 440 m. From the upper part, just beneath the Hsiangchi series, some small brachiopods and pelecypods were collected.

From Chiehtuochiao (解脫橋), a wooden bridge built below the stair

1. Y. T. Chao and T. K. Huang, The Geology of the Tsinglingshan and Szechuan. p. 153.

steps of Leiyinssŭ, going to south for about 5 km. we reached Hsinkaissu (新開寺) which lies on a hill 1500 m high. In the environs of the temple many small buildings are scattered here and there on the slopes. Most of them are used as summer resorts.

Not far south from Chiehtuochiao the Chialingchiang limestone is underlain by purple sandstone and shale, dipping at 60°-70° to S 70° W with a thickness of nearly 200 m. Although no fossil has been found in this series, it can be compared with the Feihsienkuan[1] formation (飛仙關層) of Lower Triassic in having the same rock characters and stratigraphical succession.

Below the Feihsienkuan purple shale and sandstone, we found a massive sheet of dark-green and gray basaltic lava of more than 100 m in thickness, the general characters of the lava, when observed on hand specimen, may be briefly described. It shows a fine texture, consisting occasionally of phenocrysts of white plagioclase with a length of 1 cm or more and a dark green groundmass. The Amygdaloids contain quartz and calcite. The rock is slightly magnetic and rather dense. It is usually weathered to fragments covering the cultivated slope, and thereby the outcrops are not clearly visible.

On the upper slope of the Hsinkaissŭ hill, all the outcrops are of the dark-gray and bluish-gray massive limestone, which occasionally gives out a bituminous odor after a fresh strike. In its lower part the limestone is not so pure as that of the upper, but often intercalated with dark-gray and easily weathered shales. They dip variably at 55°-88° to N 40° W and S 40° W. The total thickness amounts to about 400 m.

In the intercalations of impure limestone and dark shale of the lower part, we collected some large brachiopods, according to Mr. T. K. Huang they are:

Cryptospirifer omeishanensis Huang
Cryptospirifer striatus Huang
Cryptospirifer semiplicatus Huang.

1. Y. T. Chao and T. K. Huang, The Geology of the Tsinglingshan and Szechuan, p. 152.

Another collection was made at a horizon about 200 m from the bottom from a rather pure limestone. The fossils belong to few species, though they are represented by abundant individuals. Mr. Huang gives the following list:

Martiniopsis omeishanensis Huang
Athyris subtriangularis (Reed)
Schizophoria sp.

Still higher at a horizon not far from the contact with the overlying lava, the gray limestone yields the following fossils.

Wentzelella timorica (Gerth)
Neoschwargerina sp.

According to the identification of the fossils, the limestone should be included in the middle Permian or the Yanghsin formation, which is divided into Chihsia and Maok'ou limestones by Mr. Huang.[1]

When coming down from Hsinkaissŭ, we took another path on the northwest of the former one, where the yellowish-gray shale and thin-bedded sandstone occur at Leitap'o (雷打坡) and underlie the Yanghsin limestone (on map we use the name Chihsia for it). A collection of trilobites from the yellowish-gray loose shale was made, according to Dr. Y. C. Sun the fossils belong to the Ordovician and are represented by the following species :

Taihungshania shui Sun
Acidaspis tani Sun
Illænus omeishanensis Sun
Illænus sp.
A Pelecypod shell (imperfect)

From Leitap'o coming down along the stream, we met the same limestone as that of Hsinkaissŭ, with an exposure of about 700 m along the path dipping to N 45° E nearly vertically. *Michelinia microstoma* Yabe et Hayasaka was collected from the lower part of the limestone and *Martiniopsis omeishanensis* Huang from the middle part at Kaotungk'ou (高洞口). Further down we passed through the outcrops of lava and purple sandstone and shale of the Feihsienkuan formation and returned to Chiehtuochiao.

1. T. K. Huang. The Permian formations of southern China. Mem. Geol. Surv. China. Ser. A, No. 10, p. 92.

From Leiyinssŭ to Chingyinko—Following the path from Leiyinssŭ to west all the outcrops are purple sandstone and shale dipping to SE with the dipping angles gradually decreasing westward. When passing through Huayenssŭ (華嚴寺) and Shunyangtien (純陽殿) we found again the Chialingchiang limestone which extends from Fenghuangp'ing with the bedding nearly horizontal. On the west of Huitengssŭ the overlying mantle of the limestone was eroded away and in turn the Feihsienkuan purple-red sandstone and shale are reexposed in a wide area including the localities of Ta-o-ssŭ (大峨寺) Chungfengssŭ (中峯寺) and Lungshengkang (龍昇崗), dipping at 10°-20° to N 10°-26° E and N 45° E.

In the vicinties of Kuangfussu (廣福寺) and Chingyinko (清音閣) the dark basaltic lava crops out again, with the same characters as that at the slope of Hsinkaissŭ, but not so profoundly weathered on the surface, dipping at 30°-70° to N 60° E. At the foot of Chingyinko there are gorge-like narrow valleys on which a pair of bridges were built, named Shuangfeichiao (雙飛橋) or Double-flying bridges, they were originally formed along some fissures in lava. The two streams, one coming from Shihhsunkou (石筍溝) and the other from Hungchunp'ing (洪椿坪) meet below the double bridges.

From Chingyinko to Chiulaotung—From Chingyinko northwestward there is a path leading to Wanniensssŭ (萬年寺), while southwestward there are two ways, one to Hungchungp'ing and the other to Tapingssŭ (大坪寺). We went to the latter first, skirting along the hill slope behind Chingyinko. For about 300 m, the lava is underlain by the Permian massive gray limestone which dips to northeast and extends westward to Niuhsinssŭ (牛心寺), where we met the weathered fragments of yellowish-gray shale and sandstone, with the same characters as that occurring at Leitap'o, but no fossils were found. A little further west, the yellowish-gray sandstone and shale are in contact with some white-gray limestone, which is quite different from Permian limestone by its broken and brittle character. Mr. Chao named it the Hungchunping limestone and correlated it with the Tengying limestone of Sinian age in Yangtze gorges. Some small intrusions of granite were found in the limestone near the path between Niuhsinssŭ and Huifossŭ (會佛寺). Circular laminations usually take place on the polished surface of the limestone ranging from few millimeters to more than one centimeter in diameter. They are unlike *Collenia* which is characteristic of the Nank'ou limestone in North China, but may be formed by secondary agencies. Huifossŭ and Tapingssŭ are two temples, both situated on the Hungchunping limestone, respectively situated at 1,210 and 1,400 m.

After coming back from Tapingssŭ to Kuangfussŭ, we started for Hungchunping by taking another path along the stream southwestward, within a distance of 300 m, the outcrops consist entirely of dark-gray lava below which we found the Permian limestone dipping at 60° to N 30° E. The thickness of the exposed parts is 300 m or more. From the lower part we found some small brachiopods and a curved cephalopod, which can not be determined on account of their poor preservations. Cherty nodules are found at some localities. Further south we passed through two narrow gorges, both of them are composed of the Permian limestone. One of the gorges has a depth of 30-40 m, with the walls only 4-5 m apart from each other, this is called Heilungchiang (黑龍江) by the natives. Beyond the gorge, where the valley is slightly wider, the Ordovician shale seems to be present, since the outcrops have already been found at Niuhsinssŭ and Leitap'o which are situated north and south of this locality respectively. But the slopes are thickly covered by ever-green groves, though a small outcrop of yellowish-gray quartzite with pyrite crystals has been found.

A little further southwest, the Sinian limestone appears to be in contact with the Ordovician shale and sandstone by a normal fault, with the downthrow on the N E side. This fault was first recognized by Mr. Chao. But Dr. Heim considered that here is the NE limb of a simple anticline and the lacking of Cambrian strata is due to the granite intrusion. It seems to us that the granite intrusive body is confined to the Sinian limestone and does not affect the strata beyond it. The Sinian limestone has been metamorphosed, resulting in its crushed and crystalline characters; no additional metamorphism can be observed as affected by the granite intrusion. No trace of granite was found in the adjacent Ordovician and Permian strata. Some pyrite crystals were found in the Ordovician quartzite, which do not necessarily indicate contact metamorphism.

The Sinian limestone is well developed in the environs of Hungchun-p'ing, by which name Mr. Chao designated it. The prevailing strikes are NW and SE and the dips to NE with dipping angles of 20°-30° on the east of the temple and to SW with dipping angles of 10°-20° on the west, this showing the presence of a symmetrical anticline with the axis lying at 1 km west of the Hungchunp'ing temple. In the narrow valley below the temple, another granite body occurs at the position of the anticlinal axis, which Dr. Heim considered it to be the nucleus of the great Omeishan anticline, and of Pre-Sinian age. This granite is different from that found at Niuhsinssŭ and Heilungchiang in the coarse-grained texture and the presence of flesh-red feldspar. But the gneissic texture is absent in both granites. Since the real contact is not clearly shown, it should be questioned whether the granite is an intrusion of a later age or belongs to the Pre-Sinian as Heim suggested. The green rock dyke described by Heim as being cut off by the overlying ~~limestone,~~ was not seen by us in this valley. Mr. Foster mentions that he has found some basic rock dykes in the granite gorge near Ssŭchiping[1] (四季坪). It is not known whether the green rock dyke mentioned by Heim is the basic rock dyke found by Foster. The question needs further investigation.

Proceeding further and climbing up to an elevation of 1800 m we reached Chiulaotung (九老洞), a beautiful temple below the lofty cliff. All the strata exposed below Chiulaotung are the Hungchunp'ing limestone, while those above it belong to younger formations. According to the difference of elevations and the inclinations of the strata, the thickness of the Hungchunp'ing limestone between the contact with the granite in the valley and its top at the foot of Chiulaotung can be calculated, it is about 800 m.

From Chiulaotung to Tachengssŭ—Above Chiulaotung the overlying formations form the steep cliff behind the temple. Within the lower 230 m the strata are composed of deep-gray and purplish-gray sandstone and sandy shale immediately on the Sinian white-gray limestone. The contact surface can clearly be seen along the path between Chiulaotung and Yühsienssu (遇仙寺).

1. C. L. Foster. Notes on Szechuan Geology, Journal of the West China Border Research Society, Chengtu, Vol. I, 1922-1923, p. 4.

On account of the sudden change of the rock characters, it shows that there was a distinct interruption of sedimentation after the Hungchunping limestone was deposited, the limestone having undergone a considerable erosion. So we propose to include this formation, which Mr. Chao named the Chiulaotung series, in the Cambrian rather than in the Sinian as he suggested.

Along the cliff going to northwest, we reached the temple of Yühsienssŭ at the elevation of 1,780 m. Below it the Chiulaotung sandstone and shale are overlain by yellowish-gray sandstone and shale, greenish-gray calcareous shale, shaly limestone and occasionally oolitic limestone dipping at 10°-17° to N 75° W with a thickness of 145 m. Owing to the development of this formation around the temple, it is named the Yühsienssŭ formation. At a short distance northwest of the temple and at a horizon about 35-50 m from the base of the formation we collected many fossils from a dark-gray calcareous shale, which were first discovered by Mr. Chao. The fossils include the following species:

Redlichia nobilis Walcott
Ptychoparia ligea Walcott
Omeishania yuhsienssŭensis Sun
Obollela sp.

Mr. Chao regarded the formation as belonging to the lower Cambrian and correlated it with the Shipai shale in the Yangtze gorges above Ichang. From the temple further up to Lienhuashih (蓮花石) all the outcrops are of the same formation, but some of the higher peaks are capped with younger strata. South of Lienhuashih the yellowish-gray shale in the upper-most part of the Yühsienssŭ formation, yields some small trilobites. They are identified by Dr. Y. C. Sun to be a new species:

Ptychoparia szechuanensis Sun

Further south, we climbed up a steep cliff named Tzuantienp'o (鑽天坡) "Sky-piercing mountain", on which the temple Hsihsiangchih (洗象池) is situated at the elevation of 2,110 m. On the slope and in the vicinity of the temple, rocks are mostly concealed under dense groves, only a few outcrops show that this division is composed of gray limestone, calcareous shale, conglomeratic limestone and white-gray pure limestone, dipping at 13°-17° to S. 70° W with a thickness of about 220 m. No fossils were found. This series was named by Mr. Chao the Hsihsiangchih formation, including the overlying division, which is now separated to form the Tachengssŭ formation.

Within the interval between Hsihsiangchih and Tachengssŭ (大乘寺), for about 2 km. in distance, the surface is almost entirely covered by ever-green trees. It can be inferred from the fallen debris and the pavement stone that the essential rocks here consist of greenish shale, shaly sandstone, gray quartzitic sandstone, and brownish, purplish and green sandstone and shale, from which no fossils have yet been discovered. The thickness is approximately estimated at 160 m. From the Stratigraphical position and lithological characters we correlate this formation with that at Leitap'o, near Hsinkaissŭ, in which many Ordovician fossils were collected and have been studied by Dr. Y. C. Sun as already mentioned above. But Mr. Chao included it in the Hsihsiangchih formation and regarded it as being a part of Upper Cambrian. Dr. Heim on the other hand suggests it to belong to the Silurian, his statement will be quoted as follows:

"According to my preliminary observations the lower Palæozoic is divided into following divisions:

"a. Lower ....

"b. Upper, characterized by gray slate and marls of 80-100 m. (Shinkaisze). It is apparently this upper division which has furnished a Monograptus found by Foster. Thus Silurian might be present, especially an equivalent of Lungma shale of the Yang-tze gorges...."

It is not known exactly what kind of fossil was found by Mr. Foster and whether the fossil belongs to real graptolites. As we have already mentioned before, this division yields determinable Ordovician fossils, thus it is neither Cambrian nor Silurian, but definitely belongs to the Ordovician. We propose to give it a new name the Tachengssŭ formation.

From Tachengssŭ to Chiehyintien — To the southeast of Tachengssŭ we climbed up a cliff of about 150 m in height named Yenwangp'o (閻王坡), upon which there is a platform with an elevation of 2,450 m, sloping gently to the northwest and abruptly terminating on the southeast to form the precipitous cliff below. Along the cliff edge to south-west, it extends as far as to Chiehyintien (接引殿) with two temples Paiyunssŭ (白雲寺) and Leitungp'ing (雷洞坪) standing in the northern part. On the platform, above Tachengssŭ, all the rocks are dark-gray massive limestone with bituminous odor and occasionally with black shales in some part. The prevailing strikes are S 70°-40° E more or less parallel to the cliff edge, and the dips are at 10°-20° to northwest. From the lower part of this limestone, the following fossils were collected by Mr. Chao near Tachengssŭ.

Tetrapora nankingensis Yoh
Stydiophyllum gnomeiense Huang
Polythecalis cf. *yangtzeensis* Huang
Wentzelella szechuanensis Huang.

From the same locality we got another collection of the same fauna. The upper part, exposed in the vicinity of Chiehyintien has not been studied in detail, owing to the covering of snow. On the path between Paiyunssŭ and Leitungp'ing many fossil sections are visible on the polished surface of the pavement stone, most of which are transverse sections of brachiopods.

This sequence of limestone is equivalent to that occurring at Hsinkaissŭ and regarded as being the Chihsia limestone of Middle Permian age, but the thickness is slightly reduced in this part.

Above Chiehyintien — During the foregoing days we worked almost every day under bad weather with heavy mist. After coming up to Chiehyintien at the elevation of 2,539 m, we were on the level above cloud strata. From here upward we proceeded under bright sun shine, though the lower slopes were still drowned in thick fog. Moreover the vegetation also becomes less abundant, so that our work could proceed more conveniently.

From Chiehyintien we climbed up another cliff named Chilip'o (七里坡) which is 2,800 m above sea level. All the outcrops on the slope are dark-greenish-gray volcanic lava, with white prismatic crystals of plagioclase and occassionally with amygdaloidal cavities filled up with calcite and quartz. It has a strong magnetic property, attracting the compass needle for about 10 degrees. When we made the surveying on the slope of Chilipo, the back sight from the instrument to Chiehyintien did not coincide with the line of azimuth of compass by a difference of 5 or 6 degrees. This magnetic power is due to the abundant ferriferous minerals in the lava.

From Taitzŭp'ing (太子坪) going southeastward about 1.3 km, passing through the temples of Yungchingssŭ (永慶寺), Tzushihtien (祖師殿), Chenhsiangt'a (沉香塔), Tienmenshih (天門石), Ch'itiench'iao (七天橋) and P'uhsient'a (普賢塔) we reached the top of the mountain, on which the temple Chinting (金頂) or the Golden-Peak is situated at the elevation of 3,035 m as measured by our plane table surveying. Behind the temple the cliff stands uprightly for thousand meters.

On the summit—Looking around from the peak one can not help being deeply impressed by the thick white clouds surrounding the mountain. When facing to east, nothing can be seen but the boundless cloud sea thickly spread below the stupendous cliff. While on the other side, facing to west, the mountain surface gently slopes down to west along with the direction of the inclination of the strata and submerges into the clouds at moderate distance. But when looking off farther to west there could be seen the high mountain peaks projecting out of the clouds and standing row by row in the north-southern direction. Among these island-like peaks in the cloud sea most were covered with heavy snow, which are the well known snow mountains in Hsikang. The highest one of them, named Kungka (貢嘎) is situated between Tachienlu and Chiulung (九龍) with a height of 7,500 m as surveyed by Dr. Heim[1].

On the south of Chinting, there are two other peaks on the cliff edge, they are Chienfoting and Wanfoting (千佛頂, 萬佛頂). The latter is a little higher than Chinting and amounts to 3,047 m in elevation.

1. A. Heim: Szechuan-Tibet—Expedition der Sunyatsen-Universitat, Canton. Sonderabdruch aus der Zeitschrift der Gesellschaft für Erdkunde zu Berlin, 1931, Nr. 7/8, p. 289.

All the rocks above Chiehyintien are basaltic lava. At some localities near Chinting and Wanfoting it is tinted with reddish color from the oxidation of ferriferous minerals.

Coming down from Chinting to Wannienssu—Following the original path, we came down from the top as far as to Huayenting (華嚴頂) whence we continued our work along another path. Huayenting is situated on a small peak with an elevation of 1950 m not far from the junction of the two paths. The rocks capping the peak are the gray impure limestone which belongs to the Hsihsiangchih formation, with the typical character as has been mentioned already. Along the ridge to northeast, the gray shale and sandstone were seen to be under the impure limestone and recognized to belong to the Yühsienssŭ formation by the lithologic characters and the continuation from those at the Yühsienssŭ temple. Until to Chutien (初殿) the Yühsienssŭ shale and sandstone are immediately followed by the Hungchunping white limestone of Sinian age. The lacking of the Chiulaotung formation between them may be due to a fault with the down-throw side on the southwest.

From Chutien through Changlaoping (長老坪), Hsihsinso (息心所) and to Kuanhsinting (觀心頂) all the outcrops encountered are the Sinian limestone dipping at 16° to S 60° W near Chutien and 20°—30° to N 25° E and N 80° E below Changlaoping. Thus there is a symmetric anticline with the axis at the locality midway between Chutien and Changlaoping, extending southeastward to Hungchunping.

At Kuanhsinting, the elevation of which is 1300 m, the Sinian limestone is immediately followed by the Permian massive limestone dipping at 21° to east. The latter limestone is continuous with those at Niuhsinssŭ, Heilungchiang and Hsinkaissŭ, which have been visited before. The contact line between the two different limestones lying in northwest and southeast direction is the trace of a great fault, the down-throw side being composed of the formations of early Palæozoic on the northeast. This fault was first recognised by Mr. Chao.

Below Kuanhsinting, the slope is rather steep in a grade of nearly 30 degrees. The limestone exposed is not more than 200 m in thickness, and then succeeded by the basaltic lava. The latter is profoundly weathered, leaving only small fragments on the slope. Judging by the greenish-gray debris of the lava, it seems that its distribution is limited in a small area only 200 m in width. Upon the lava there occurs the sequence of purple-red shale and sandstone of the Feihsienkuan formation of Lower Triassic, dipping at about 20° to N 40° E. The temple Wannienssŭ (萬年寺) is situated on this formation at the height of 1,041 m.

We made a short side excursion from Wannienssŭ to north, the outcrops along the path are the purple sandstone and shale, extending as far as 2.5 km. At first the strata dip at 20° to N 50° E, finally changing to N 5° W with the dip angle slightly decreased to 15°. On the south of Ch'ip'ing (七坪) the Triassic sandstone and shale are succeeded by the white-gray brittle thin-bedded and massive limestones of the Chialingchiang formation. The limestone dips almost to N 10° W and N 30° W with the dip angle varying from 15 to 30 degrees. A stream flows across the limestone, cutting a narrow gorge of several hundred meters in length.

Passing through the gorge further north to Luokou (羅溝) we found the gray sandstone and shale of the Hsiangchi coal series lying without noticeable disconformity on the Chialingchiang limestone and dipping gently to northwest. At the time of our visit some small coal mines were being worked at Liyao (李窰). According to the informations of the miners there are four workable coal seams with the thickness of 40, 30, 15 and 30 centimeters. Some plant fossils were collected, one of them can be recognized as *Neocalamites hoerensis* (Schimper). On the north of Luokou, the coal-bearing sandstone and shale are succeeded by the purple-red sandstone and clay of the Tzuliuching formation.

To the south of Wannienssŭ, we made another side excursion. When going down to Shihhsunkou we passed through the outcrops of lava and the Permian massive limestone, then crossed the fault and finally met the Sinian limestone. When returning from Niuhsinssŭ and Chingyinko, the Sinian white-gray limestone, the Permian gray massive limestone and basaltic lava were again observed.

From Wannienssŭ to Lungmentung—From Wannienssŭ coming down, nearly along the strike to southeast and passing the temples of Chinlungssŭ

(金龍寺) and Pailungtung (白龍洞) we reached Wuhsienkang (五顯崗) where the Feihsienkuan purple sandstone and shale dip at 10° – 20° to northeast.

Further east within the interval between Wuhsienkang and Liangfengkang (涼風崗) the dip of the Feihsienkuan formation gradually changes to southwest instead of to northeast at 27 degrees. The Feihsienkuan purple beds are underlain by the basaltic lava. Between the two outcrops of lava on the southwest of Wanniensssŭ and at Liangfengkang there is evidently a broad gentle syncline, with the Feihsienkuan purple beds forming the central part. Mr. Chao made a mistake when he took the Feihsienkuan beds for the Cretaceous red beds; this made him conclude to the presence of an unconformity[1] between the Permian lava and the Cretaceous red beds. Dr. Heim repeated Mr. Chao's mistake in regarding the purple sandstone and shale as being Cretaceous red beds but he did not believe that there was a pronounced orogenic movement before the deposition of the red beds. He contended that there is only a local unconformity, since the red beds are completely concordant with the underlying Jurassic coal-bearing series at adjacent localities[2]. But in reality the sequence in this part is not different from that in other places. There is no evidence of any kind of an unconformity below the Cretaceous.

The outcrops of lava are spread in a width of 600 meters and end at a locality east of Liangfengkang. At a first glance one is easily misled by its apparent great thickness. But from further study on the structure one can see that the lava is repeated in two limbs of a closed and overturned anticline with the axis lying near the small building of Watuanshan (挖斷山).

On the opposite side of the valley the underlying Permian limestone is exposed by an anticline rising to a height of more than 100 m above the river bed. The limestone is easily overlooked on account of the indiscernible appearance and mantling of lava. But at the conspicuous point on the valley wall, one can see some small water falls pouring out from some small caves a little higher above the river bed. This condition is scarcely seen in other rocks than limestone.

1. Yatseng T. Chao: Geological Notes in Szechuan, Bull. Geol. Soc. China, Vol. VIII, No. 2, 1929, p. 143.
2. A. Heim: Structure of sacred Omeishan, Bull. Geol. Soc. China, Vol. IX, 1930, No. 1, pp. 68, 69.

The axial plane of the anticline is inclined to west, the strata of the western limb dip rather gently at about 30° to southwest, while those of the eastern limb are vertical and overturned (Fig. 2).

In order to know the extent of the anticline we passed through the river and the small ridge of Watuanshan to go to north by west as far as to Leiyai (雷崖). Between the two mentioned localities, Watuanshan and Leiyai, the Permian massive gray limestone crops out in large area. The outcrop of the limestone is enclosed by lava flow, this showing the form of an irregular dome-anticline. Above the lava occur the wide-spread Feihsienkuan purple shale and sandstone.

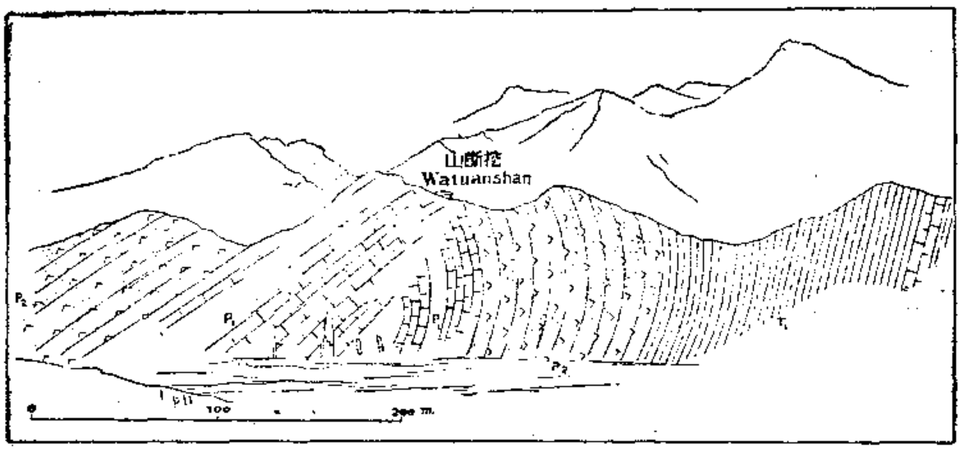


Fig. 2. Diagramatic section showing the Watuanshan anticline, P_1, Permian limestone; P_2, Omeishan basalt; T_1, Feihsienkuan purple sandstone and shale.

From the locality east of Liangfengkang to further east for a distance of 300 m, all the exposed rocks are purple sandstone and shale with purplish-gray and greenish-gray calcareous shale, striking NW and SE and dipping either to east or somewhere to west both nearly vertically. On account of its resistance to the weathering the calcareous shale forms a rocky bar standing in the river which is called by the natives the Shihchuantzŭ (石船子) or rocky boat.

On the east of Tiehsochiao (鐵索橋) the rocks change from clayey shale to purple calcareous shale alternating with gray thin-bedded limestone, and finally to white-gray pure limestone of a considerable thickness, dipping at 70°-80° to SWW and occurring within a width of 500 m. The stream flows cutting down across it to form a small gorge at Lungmentung (龍門洞). Dr. Heim collected some flattened pelecypods and ammonites from the marl in the upper part of the limestone formation. According to Dr. T. H. Yin[1] they are:

Halobia comatoides Yin
Halobia omeishanensis Yin
Halobia sp. A
Halobia sp. B
Posidonomya aff. *Wengensis* Wissmann
? Ammonites

This series is without doubt the Chialingchiang formation which extends to connect with that at Fenghuangping and Leiyinssŭ.

Marginal hills —The marginal hills on the east of Lungmentung are much lower compared with those on the west, amounting to only 100-200 m above the ground level. The rocks in contact with the Chialingchiang limestone at Lungmentung are gray sandstone and shale dipping at 60°-80° to S 65°W with a thickness of about 400 m. They belong to the Hsiangchi series which has already been mentioned to occur at Fuhussŭ where however no workable coal seams are observed. The upper part comprises the yellowish-gray coarse sandstone which is also micaceous.

Further east to Huangwan (黃灣) the yellowish-gray micaceous sandstone changes gradually to reddish and brownish sandstone and is followed by the purple sandstone and clay which are equivalent to the Tzuliuching formation. On the east of Huangwan the purple beds are in turn overlain by the brick red sandstone and clay of the Chiating formation, that is the middle part of the Red Beds. In this part the structure is rather complicated. The lower part of the Red Beds at first dips to SW and is overlain by the Hsiangchi series older in age. The strata are therefore overturned. However east of it the lower red beds turn to dip to NE; the opposite dipping directions make the structure somewhat puzzling. But careful observation in the vicinity

1. T.H. Yin, sur une petite faune de mollusques provenant de la marne Triassique d'Omeishan, Szechuan. Bull. Geol. Soc. China, Vol. XI, No. 3, 1931, p. 249-252.

of Niangkou (娘溝) revealed that the strata are very much folded and the fold comprises a closed anticline with a syncline on the west. The complexity of the structure is due to the fact that only the Tzuliuching formation or lower part of the Red Beds is more widely exposed with the overlying Chiating formation or middle part of the Red Beds mostly eroded away and the underlying Hsiangchi series entirely concealed beneath. The structural feature is shown in the adjoining figure (fig. 3).

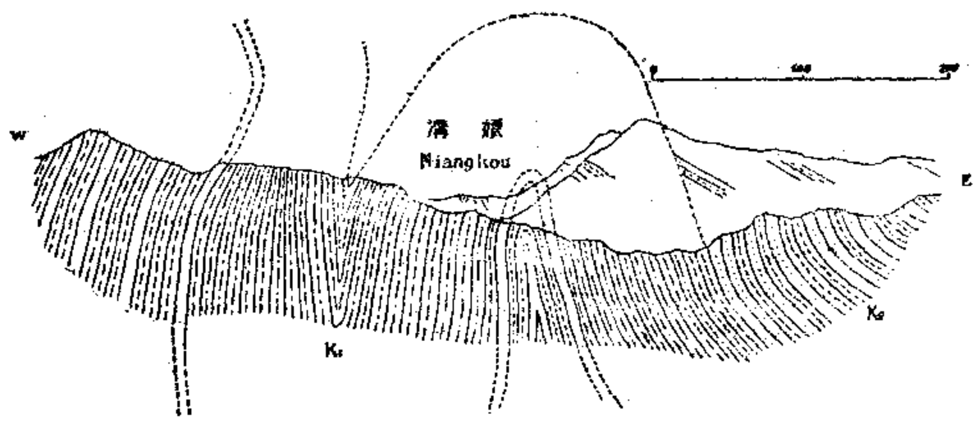


Fig. 3. Profile showing the Niangkou fold, K_1, Tzuliuching formation; K_2, Chiating formation.

The hillocks from here become lower and lower eastward and submerge into the low land in the environs of the Omei city. Rock outcrops are scarcely seen, but on some of the scattered low spurs the red soil shows its derivation from the red sandstone and clay of the middle part of the Red Beds. The land surface is entirely covered by Quaternary gravels and alluvium, the former being occasionally exposed but usually concealed beneath the latter.

About 4 weeks were spent for both surveying the topographical map and making the geological study. It is a matter of regret that our work was much hindered by the rainy and foggy weather and about one-third of the time spent has been wasted on account of this hinderance.

STRATIGRAPHY

The stratigraphical succession of Qmeishan has been worked out by Mr. Chao in 1928 and somewhat supplemented by Dr. A. Heim. Most of the formations from the pre-Sinian to the Cretaceous are represented with a great hiatus between the Ordovician and the Permian. From our observations, some additional suggestions may be further offered. First, the Chiulaotung formation which was regarded as Upper Sinian by Mr. Chao is better grouped into Lower Cambrian; and secondly since the Ordovician trilobites were found from the upper part of the Hsihsiangchih formation of Mr. Chao's division, this part should be separated from the Hsihsiangchih formation and forms an independent division representing the Ordovician. It is named the Tachengssŭ formation. With these revisions the formations of Omeishan are tabulated in ascending order as follows: (Pl. II)

Quaternary...............	Gravels and superficial soils	
	Unconformity	
Cretaceous......	Chiating formation	
	Tzuliuching formation	300 m
Jurassic........	Hsiangchi coal series	400 m
	Disconformity	
Triassic	Chialingchiang formation..	380-440 m
	Feihsienkuan formation.......	200 m
	Disconformity	
Permian........	Omeishan basalt..............	350 m
	disconformity	
	Chihsia formation.............	400 m
	Great hiatus and disconformity	
Ordovician......	Tachengssŭ formation	160 m
	Disconformity	
Cambrian	Hsihsiangchih formation.......	220 m
	Yühsienssŭ formation	135 m
	Chiulaotung formation	230 m

disconformity

Sinian...............Hungchunping formation .... 800 m

unconformity

Pre-Sinian............Granite

PRE-SINIAN

Granite

The granite occurring in the valley below Hungchunp'ing is perhaps the oldest rock in the Omeishan area. It was first described by Professor C. L. Foster, who found it from Ssuchip'ing (四季坪) below the Omeishan front cliff. He was the first to observe that the granite suffered a considerable erosion and is in contact by an unconformity with the overlying sedimentaries. If this is true, the granite must be Pre-Sinian. Unfortunately we did not visit the place mentioned. However, from the stream, which flows from Ssŭchip'ing, the granite pebbles and boulders were seen and collected.

According to Heim the granite in the gorge below Hungchunp'ing forms the nucleus of the great Omei-anticline. It lies under the Sinian limestone with an even surface, which might have been caused by glacial action. He also found the dyke of some green fine-grained basic rock being cut off by the overlying limestone.

We have visited the locality mentioned by Heim. Unfortunately owing to the covering of groves, the real contact surface of granite and its overlying limestone could not be clearly observed. Moreover, as the Sinian limestone itself is already somewhat metamorphosed, it is difficult to say whether it has been further metamorphosed by the granite. On the other hand, the granite has no gneissic texture to show the anamorphism in the pre-Sinian time. Therefore our observation brought no evidence to prove whether the granite is pre-Sinian or intruded in later age. The dyke described by Heim as cut off by the overlying limestone was not found by us. Foster mentioned that the green dyke at "Granite gorge" near Ssŭchip'ing is intruded into the granite body.

It is unknown whether this is the dyke what Heim states. From its appearance this granite is different from that of Niuhsinssŭ and Heilungchiang in its coarse-grain, greenish-white color, containing flesh-red and white-greenish-gray feldspar in large crystals and lesser amount of mica. Under microscope it shows granitic texture, consisting of an abundance of plagioclase with zonal texture and fine repeated twins; large quantity of quartz; lesser amount of orthoclase partly altered to kaolin; biotite often green or yellowish-green in color partly altered to chlorite and occasionally bent or folded. The accessory minerals are magnetite and aptite in very small quantity. Graphic texture is sometimes present with quartz crystals intergrown with feldspar.

It is true that the thickness of the Sinian limestone overlying the granite is estimated at about 800 m. This seems to reach a maximum figure as compared with the total thickness of the Sinian system in Yangtze gorge, including all the three formations, the Nantou, the Toushant'ou, and the Tongying. It is therefore reasonable to expect that below the thick sequence of the Sinian limestone occur the pre-Sinian rocks. We therefore provisionally accept the pre-Sinian age of the granite as proposed by Foster and Heim, however still expecting to make further investigation.

SINIAN

Hungchunp'ing formation

The Hungchunp'ing limestone is white-gray, gray and dark-gray in colour, in part crystalline, and silicified though without flint and chert nodules or layers. In the environs of Tap'ingssŭ and at some locality west of Hungchunp'ing the limestone shows some small mammillary protuberances on the bedding plane, ranging from half to one centimeter in size. It is not easy to explain the origin of this structure, and its form offers no resemblance to *Collenia*.

CAMBRIAN

Concordantly upon the Sinian limestone occurs the Cambrian sandstones shales and impure limestone, which are divided into three, namely, the Chiulaotung, Yühsienssŭ and Hsihsiangchih formations. These names were first proposed by Mr. Chao, who regarded the Chiulaotung formation as a part of the Sinian and compared it with Hsiamaling shale in western hills of Peiping. According to our observations it is better to be included in the Cambrian. And from the upper part of the Hsihsiangchih formation is separated another division, the Tachengssŭ formation, which belongs to the Ordovician and will be described later.

Chiulaotung formation.

This is the lowest part of Cambrian, consisting of purplish-dark shale, purple-dark sandy shale, purple-yellowish and dark-gray sandstone occasionally with thin-bedded limestone in the lowest part. No fossil has been found. Its contact with the Sinian limestone is clearly shown at the locality midway between Chiulaotung and Yühsienssŭ, where the limestone below and the sandy shale above are concordant each other.

The sandstones are used as building stones and for paving the roads. Both the sandstone and shale are scarcely metamorphosed, though some sandstone is quite compact. The resemblance of the rock characters to the overlying formation much closer than to the underlying limestone shows that the deposition continued upward rather than following the Sinian limestone. It may be compared with the lower part of the Shipai formation in the Gorge district above Ichang[1], which is also unfossiliferous. The Chiulaotung formation is thus supposed to be of early Cambrian age. The formation usually forms cliffs and is spread in long narrow area, with the thickness amounting to 230 m.

Yühsienssŭ formation.

This formation conformably overlies the Chiulaotung sandstone and shale. It is well exposed in the environs of Yühsienssŭ, Lienhuashih and Chutien, though locally capped by the Hsihsiangchih limestone on some higher peaks. The essential constituents are gray shale, calcareous shale, gray limestone and yellowish-gray quartzitic sandstone. Occasionally there is a layer

1. J. S. Lee, Geology of the Gorge district of the Yangtze, Bull. Geol. Soc. China, Vol. II, No. 3-4, 1924, p. 365.

of red thin-bedded sandstone at the top. Oolitic limestone is also present in the upper part. The total thickness is 145 m.

Fossils were collected from the horizon at about 40-50 m above the base of the formation. They are:

Redlichia nobilis Walcott
Ptychoparia ligea Walcott
Omeishania yuhsienssuensis Sun (gen. & sp. nov.)
Aluta sp.
Obollela sp.

Higher up, near the top of the formation, another trilobite was found in yellowish-green shale,

Ptychoparia szechuanensis Sun (sp. nov.).

All the fossils belong to Lower Cambrian, the latter one representing the upper part. When correlated with the section in Yangtze gorge, this formation seems to be equivalent to the upper part of the Shipai shale.

Hsihsiangchih formation.

This is the upper division of the Cambrian system, consisting mainly of gray impure limestone, calcareous shale and conglomeratic limestone or Wurmkalk. The formation has a probable thickness of 220 m. It is mostly concealed under the dense vegetations, no fossils could be found.

This formation together with the underlying two, extends from Hsihsiangchih in the north-south direction, forming the middle part of the Omeishan cliff. Scattered outcrops are found on the isolated peaks of Huayenting and Lienhuashih.

The name Hsihsiangchih formation was used by Chao for designating the whole sequence above the Yühsienssŭ series and below the Chihsia limestone, with the now separated Tachengssu formation included, which he supposed to belong to the Cambrian system. The upper two formations of Mr. Chao's division, excluding the Chiulaotung series, were combined and redivided by Dr. Heim into two divisions, lower and upper. The upper part is characterized by gray slates and marls of 80-100 m, and a *Monograptus* is said to have been found by Foster. He thus suggested to regard it as the Silurian equivalent of the Lungma shale of the Yangtze gorges.

As a matter of fact, this formation underlies the Tachengssŭ formation, which carries Ordovician fossils. If the latter is equivalent to Neichiashan series of the Yangtze gorge, then the Hsihsiangchih formation would be correlatable with the Ichang limestone. But the presence of the conglomeratic limestone similar to the Wurmkalk in North China seems to point to Upper Cambrian age. Since no reliable fossil was discovered, its age can not be definitely settled. If it belongs to Upper Cambrian as just mentioned, then this formation is entirely wanting in the Yangtze gorge, while there was an interruption of deposition in Omeishan with the Ichang limestone unrepresented. On the other hand, if it is the equivalent of the Ichang limestone then its thickness is here very much reduced, being only one-fifth of that in the Yangtze gorge. The stratigraphical succession was studied along the path between Chiulaotung and Tachengssŭ and is shown in the columnar section. (Fig. 4).

ORDOVICIAN.

Tachengssŭ formation.

The new name is proposed by us for representing the upper division of the Hsihsiangchih formation of Mr. Chao. It is well developed in the environs of Tachengssŭ, from which the name is derived. The essential rocks are yellowish-gray quartzitic sandstone and green sandy shale, with reddish and purple-brown quartzose sandstone in the lower part and greenish-gray shale at the top.

The stratigraphical succession as studied at Tachengssŭ and Leitap'o, is shown as follows:

Greenish-gray shale and sandy shale with fossils............30 m
Yellowish-white-gray and gray quartzitic sandstone and quartzite with green sandy shale and thin-bedded sandstone...80 m
White-gray and brownish quartzose sandstone...............30 m
Yellow-reddish and purple-brown quartzose sandstone with purple-red and green shale ....20 m

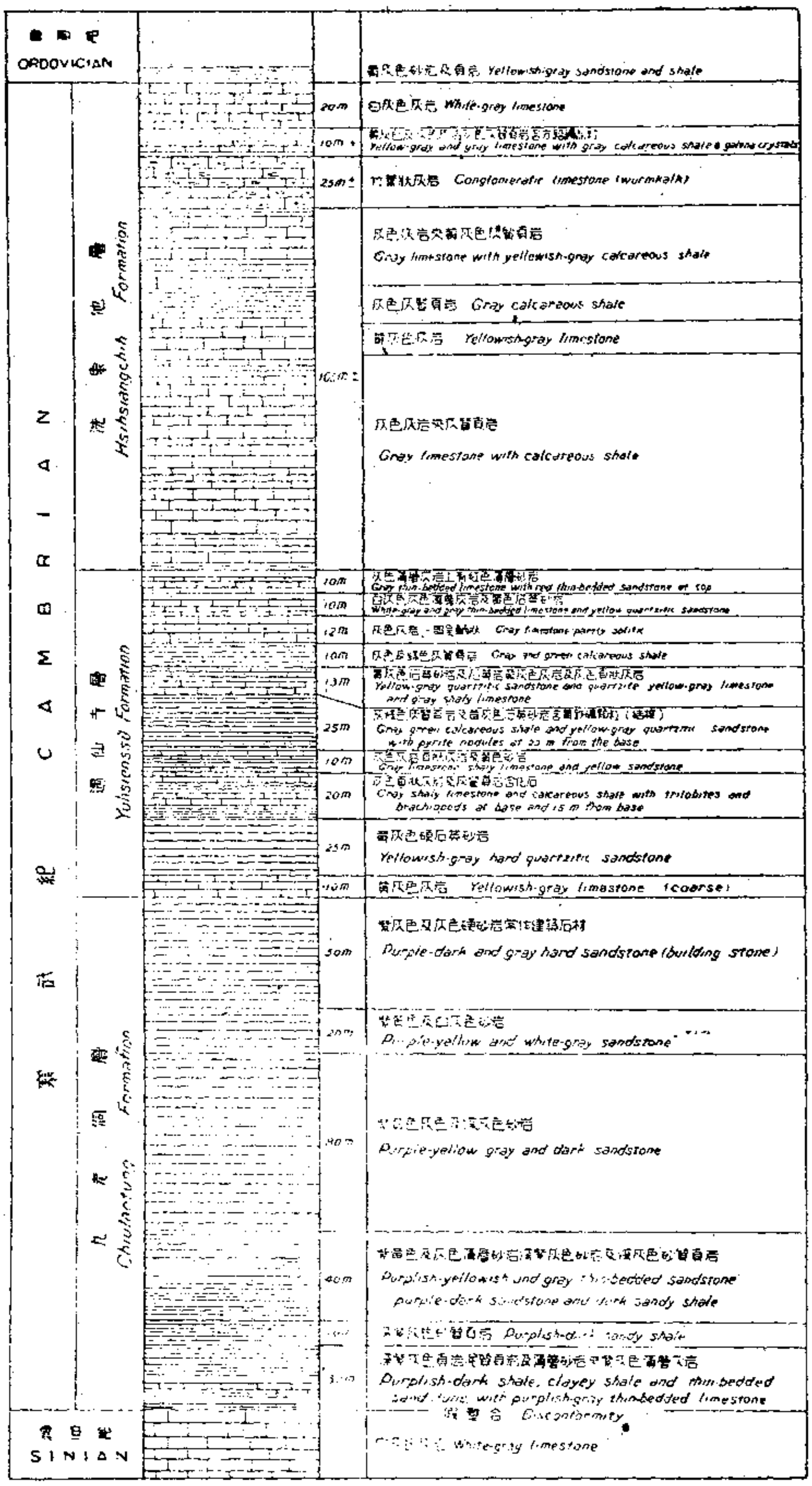


Fig. 4. Columnar section of the Cambrian formations of Omeishan.

It occurs in two belts, one on the cliff extending to north through Tachengssu as far as to Kungpeishan (弓背山), the other in the environs of Leitap'o extending to Niuhsinssu, where it is terminated by a fault.

At Leitapo, below Hsinkaissu, we found some trilobites and other fossils from the greenish-gray shale in the upper part. They are:

Taihungshania shui Sun
Acidaspis tani Sun (sp. nov.)
Illaenus omeishanensis Sun (sp. nov.)
Illaenus sp.
A Pelecypod shell (imperfect).

According to the fossils it is equivalent to the Neichiashan series of the Yangtze gorges. But the latter is abundant in limestone while the former consists entirely of sandstones and shales, this seems to indicate that the Ordovician sea became shallower here.

THE GREAT PRE-PERMIAN GAP

Directly upon the Tachengssu formation rests the Permian massive limestone, without intercalation of either the Sintan shale of the Yangtze gorge or the Devonian and Carboniferous limestone of northern Szechuan. It is not ascertained whether this area has not originally received any deposits during long period of time corresponding to the gap, or the sediments which had been deposited in the area were subsequently entirely eroded away. However, angular unconformity was not found.

PERMIAN

Chihsia formation.

The Chihsia formation in Omeishan consists of a great sequence of gray massive limestone, sometimes interbedded with dark shale, amounting to 400 m or more in thickness, and lying concordantly but disconformably upon the early Paleozoic formations. The limestone gives out a bituminous odor when struck with a hammer and includes some flint nodules. In the whole formation three fossiliferous horizons have been recognized, with the following fossils:

C. Upper horizon (not far below lava)
Wentzelella timorica (Gerth)
Neoschwagerina sp.

B. Middle horizon (in the middle part)
Cryptospirifer omeishanensis Huang
Cryptospirifer striatus Huang
Cryptospirifer semiplicatus Huang
Martiniopsis omeishanensis Huang
Athyris subtriangularis (Reed)
Schizophoria sp.

A. Lower horizon (near the base)
Michelinia microstona Yabe et Hayasaka
Tetrapora

Mr. Chao made two collections in his trip. One from Tachengssŭ contains *Tetrapora nankingensis* Yoh, *Stylidophyllum gnomeiense* Huang, *Polythecalis* cf. *yangtzeensis* Huang, *Wentzelella szechuanensis* Huang; the other collection made at Chiehyintien includes *Wentzelella timorica* (Gerth), *Rhipidomella pecosi* Marcou, *Productus* (*Gigantella*) *davidi* Bayan, *Martinia uralina* var. *longa* Tschernychew, and *Spirigerella* cf. *grandis* Waagen.

According to the nomenclature of Chinese Permian proposed by Mr. Huang[1], both the fossils collected by Chao and ourselves are of the Yanghsin formation of Middle Permian, which he subdivided into Chihsia and Maokou limestones. In the present paper, we still use the name Chihsia formation for the whole series.

Omeishan Basalt

The top of Omeishan is capped by a thick sheet of basaltic lava. It is wide-spread over the top surface gently slopping to west, and also exposed in the vicinities of Wanniensŭ and Chingyinko, extending more or less parallel to the fault line. At Liangfengkang it is folded with the underlying limestone. The thickness varies from place to place. At the top of the cliff, it is not less than 350 m, while at Liangfengkang it is estimated at only 140 m.

1. T. K. Huang: The Permian formations of south China. Mem. Goel. Surv. China Ser. A. No. 10, p. 92.

The rock is dark-green-gray in color with white prismatic crystals of plagioclase one centimeter in length. Amygdaloids are locally abundant and filled up with quartz and calcite. It has a strong magnetic power due to an abundance of ferriferous minerals in its composition. On the summit of the mountain, near Chienfoting and Wanfoting, the rock occasionally shows a reddish color is somewhat unlike that at adjacent locality. Under microscope the rock contains reddish-brown iron oxides mixed with glass, occasionally with few microlites of plagioclase. The red color of the rock is due to the abundant iron oxides derived from the decomposition of the original ferriferous minerals through weathering and oxidation. The rock collected from other localities contains abundant microlites of labradorite in the groundmass of glass. That from Hsinkaissu includes some crystals of bornite and under microscope some olivine crystals are found to occur among the phenocrysts.

Columnar structure was seen on the cliff below the temple of Chinting.

The exact age of the lava is unsettled but it may be of the lower Lopingian of Upper Permian age.

TRIASSIC.

Feihsienkuan formation.

Upon the lava sheet of basalt there rests a series of purple or purplish-red sandstone, shale and clay with intercalations of limestone in the upper part. The name "Fei-hsien-kuan" was originally proposed by Von Richthofen[1] to include the purple shales in northern Szechuan, which he regarded as belonging to the Silurian. Subsequently Messrs. Chao and Huang[2] proved that the formation belongs to Lower Triassic. In Omeishan proper, no fossil was found. Since no distinct demarkation between the Feihsienkuan formation and the overlying limestone can be established, the thickness is thus hard to be accurately estimated for each of them. The succession and thickness of the Triassic formation at two adjacent localities are shown in the columnar section (Fig. 5).

1. T. Richthofen, China, Vol. II, p. 602.
2. Y. T. Chao & T. K. Huang, The Geology of the Tsinglingshan and Szechuan, p. 152.

The contact between this formation and the underlying lava seems to be concordant. However, it is believed that there exists a break between them, and the lava has partly suffered a pronounced erosion.

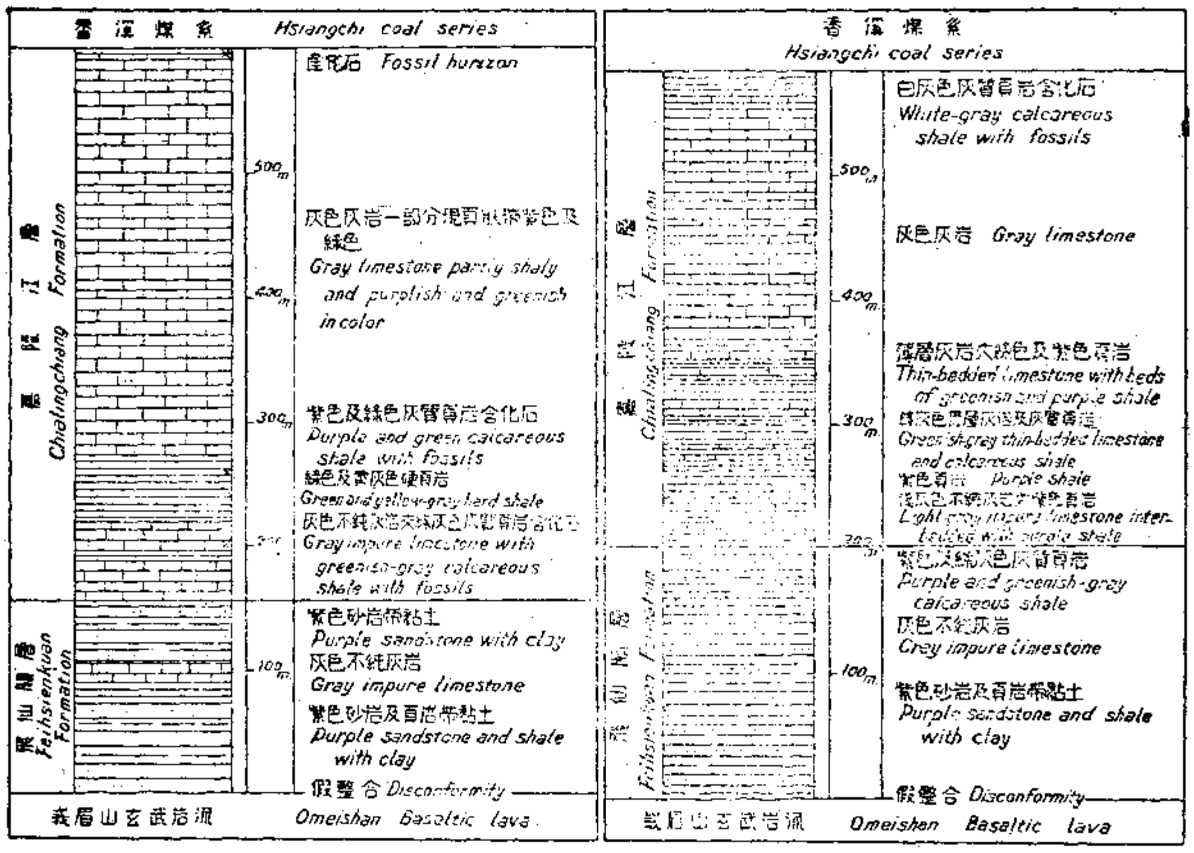


Fig. 5. Columnar sections showing the successions of the Triassic formations in the environs of Lungmentung and Leiyingssŭ.

This formation is only found on the lower slope of the mountain, while on the summit it has been eroded away and there is no rock younger than the basalt. Below Wanniensŭ and on the west of the Lungmentung gorge, it occurs in a large area extending in the north-west and south-east direction, in the central part of which the older formations are exposed owing to the presence of a small dome-anticline in the vicinity of Watuanshan.

Chialingchiang formation.

From the Feihsienkuan formation the rocks gradually change through impure limestone and calcareous shale to white-gray thick and thin-bedded brittle and pure limestone with a thickness of 380-440 m. This formation was first called the Chaohua limestone by Mr. Chao and subsequently replaced by the present name by Mr. Huang. In the vicinities of Shanchiossŭ and Leiyinssŭ there is an excellent section, which shows the whole formation and from which the succession of the strata has been studied and shown in the columnar section (Fig. 5). Three fossil horizons were found, the first near the base, the second about 60 m higher and the third at the top of the formation. All of them are poorly preserved. In the uppermost part of several tens of meters the limestone, which is rather impure and shaly, was called marl by Heim, from which he found remains of flattened Pelecypods and Ammonites as have been listed before.

The formation occurs often in association with the underlying Feihsienkuan formation and extends mostly in the northwest and southeast direction. In the environs of Chiping there is another area in which the Chialingchiang limestone is exposed.

JURASSIC

Hsiangchi coal series

The rocks of the Hsiangchi series as we found from Omeishan as well other places in Szechuan are chiefly the gray quartzose sandstone, yellowish-gray sandstone, and dark-gray shale with thin coal seams. Some plant fossils have been collected and include the following species:

Neocalamites hoerensis (Schimper)
Equisitites cf. *sarrani* Zeiller
Phyllotheca sp.
Cladophlebis cf. *kamenkensis* Thomas
Podozamites schenki Heer
Podozamites lanceolatus (Lind. et Hutt.)

At the typical locality Hsiangchi Messrs. Hsieh and Chao[1] divided the coal series into two divisions, the lower being regarded as belonging to Rhaetic and the upper to Lias. According to our field observations the upper Hsiangchi formation is continuously succeeded by the lower Red Beds without

1. C. Y. Hsieh and Y. T. Chao: Geology of Ichang & neighbouring Districts, Bull. Geol. Surv. China, No. 7, 1925, p. 58-63.

any stratigraphical break between. Since the lower Red Beds yield the Wealden fauna, it seems that the Hsiangchi formation has been deposited through the whole period of time from the Rhaetic to the upper Jurassic. Heim had the same interpretation and said: "A lithological passage was found into Cretacic Red Beds, we would have to consider the coal-bearing series representing the whole Jurassic period".

CRETACEOUS

Tzuliuching formation.

According to our extensive experience in the greater part of the Szechuan province combined with Huang's observation, the Szechuan Red Beds may be grouped into three divisions, namely, the Tzuliuching formation the lower, the Chiating formation the middle and the Mengshan (蒙山) formation the upper part. In Omeishan occur only the Tzuliuching and part of the Chiating formation.

The Tzuliuching formation contains purple-red and greenish-yellowish clayey shale with greenish-gray coarse micaceous sandstone interbedded. It is unlike that at the typical locality of Tzuliuching, where we found two beds of limestone with plenty of pelecypods. In fact the Tzuliuching limestones are confined in the area east of Chienweihsien (犍爲縣) and north-east of Ipinhsien or Hsüfu, (宜賓縣亦稱敍府), no limestone beds of the Tzuliuching formation are found to exist in Omeishan. The thickness of this formation varies from place to place. In the area here concerned it is estimated at only about 300′m.

It lies conformably upon the Hsiangchi coal series without any break between them. Although no fossil was discovered in Omeishan, the age of this formation can be inferred by correlating it with that at Tzuliuching where some Cretaceous pelecypods were found from the limestone in the lower part. It is exposed only on the foothills of the mountain.

Chiating formation.

This is the middle part of the Red Beds, containing brick red sandstone and clay. In the surveyed area it forms the low hillocks running out from the marginal foot hills. Most of the bed rocks are covered by the red soil which forms cultivated lands. Thus the thickness is undeterminable.

QUATERNARY.

Alluvium (Gravels, sands and silts)

The unconsolidated gravels of more than 30 m thick unconformably lie upon the eroded surface of the older rocks. The pebbles and some boulders are chiefly of quartzite, ranging from few centimeters to 40-50 centimeters in diameter and cemented by the matrix of yellow and orange-yellow clay. They occur on the cut surface of the road from Omeihsien to Paoningssŭ and are well developed midway between the cities of Omei and Chiachiang.

Mr. Chao called the gravel deposition the Chengtu stage and correlated it with the Malan stage of loess in North China[1]. On account of development of gravels and clear section of the Min river at Tiehchi we propose to use the name Tiehchi (叠溪) stage instead of Chengtu stage.

Along and in the river valley and on the flood plain, the surface is almost entirely mantled by sands and superficial soil of recent time.

Granite intrusion.

In the Sinian limestone were found some intrusive bodies of the granite, the location of which is quite near what is assigned to the pre-Sinian. The granite is exposed in the gorge north of Hungchunp'ing and on the slope south of Niuhsienssŭ. The rock looks somewhat different from that supposed to be pre-Sinian found from the valley below Hungchunp'ing in finer texture and lighter color. Under microscope it shows granitic texture and contains both orthoclase and plagioclase in large amount. Graphic texture is also present, quartz is less abundant than feldspars. Green and yellowish-green biotite is found in some quantity and partly altered to chlorite. The mineralogical composition is very similar to that assigned to the pre-Sinian, especially the graphic texture is common to both. Both granites contain more plagioclase and may be called adamellite.

1. Y. T. Chao: Geological Notes in Szechuan; Bull. Geol. Soc. China. Vol. VIII, No. 2, 1919. p. 148.

The age of the intrusion can not be exactly determined in this area, for the rock occurs only in contact with the Sinian limestone.

GEOLOGICAL STRUCTURE

Omeishan is situated on the western margin of the Szechuan red basin and is a part of the mountain ranges which connect with the high plateau of Hsikang and Tibet, the elevation of which is 4000-5000 m in average above sea level. It abruptly rises from the basin and is about 2500 m higher than the latter. It is essentially formed by a gentle anticline with subordinate folds and subsequently affected by faulting (Pl. III). The main structural features may be tabulated as follows:

1. Omeishan major anticline.
2. Wuhsienkang syncline and Watuanshan anticline.
3. Niangkou folds.
4. Kuanhsinting fault.
5. Chutien fault.
6. Omeishan major fault.

1. *Omeishan major anticline*—This is a major structure shown by the divergent inclinations of the Sinian limestone in the Hungchunp'ing valley and along the path from Kuanhsinting to Chutien. At the first locality the strata forming the eastern limb dip at 20°-32° to NEE and those forming the western limb at 10°-25° to NWW with the anticlinal axis lying about 1 km west of the Hungchunp'ing temple. The western limb is still capped with younger formations dipping at 10°-15° to west, while the eastern limb is faulted down, the Sinian limestone being in contact with the lower Palæozoic formations. At the second locality the same anticline extends northward with the axis lying between Changlaop'ing and Chutien in the northwest and southeast direction. The Sinian limestone dips at 24° to NE and at 16° to SW on eastern and western limb respectively and is interrupted by two faults at Chutien and Kuanhsinting. In observing the anticline as a whole, the axis tends to bend from NW and SE to N-S and pitch to north-west.

2. *Wuhsienkang syncline and Watuanshan anticline*—The down-throw side of the Kuanhsinting fault was affected by a pair of folds, which were

developed contemporaneously with the major anticline of Omeishan and probably, in addition, compressed and overturned subsequently by the influence of the faulting. One part of the folds is the Wuhsienkang syncline which is a gentle broad one extending in the NW and SE direction more or less parallel to the fault. At Wanniensssŭ and Pailungtung, where is the southwestern limb of the syncline, the beds dip at 20° to NE, while those on the other limb at Liangfengkang dip to SW at 27 degrees. In the cental part of the syncline there occur entirely the Feihsienkuan purple shale and sandstone which are easily mistaken for the lower part of the Cretaceous Red Beds. On the outer margins of the syncline the Feihsienkuan formation is normally underlain by the Permian lava and limestone, without any indication of angular unconformity.

In connection with this syncline there is the Watuanshan anticline, which is formed by bending down the eastern limb of the former syncline, with the Permian limestone forming the central core of the anticline. The strata on the eastern limb of the anticline dip to northeast at very high angle and are successively overturned to dip to southwest at angles of more than 60 degrees. It extends not far to northwest and ends in the form of an irregular dome-anticline, in which the Permian limestone crops out in the center and is enclosed by the lava and the Feihsienkuan formation.

3. *Niangkou folds*—East of the Lungmentung gorge the Lower Red Beds are overturned and dip along with the older formations to SW with high dipping angle, while the Middle Red Beds dip gently to east, and there are the folds near Niangkou (Fig. 3) where the strata form closed syncline and anticline, with axes lying in NNW and SSE direction. The syncline is somewhat isoclinal dipping at very high angles and partly overturned on the western limb. The anticline is unsymmetrical with the western limb dipping at very high angles and the eastern limb dipping more gently.

4. *Kuanhsinting fault*—At Kuanhsinting and Heilungchiang, the Sinian limestone is in contact with the Ordovician shale, Permian limestone and other formations with a normal fault between. The fault runs in the NW and SE direction nearly parallel to the strikes of the Sinian limestone and the

younger formations of the down-throw side. The fault plane is not clearly shown at the surface, however a high inclination is believed by examining the contact condition on some steep slopes. The throw is variable, smaller in the SE part where the older Palæozoic formations are in contact with the Sinian limestone and larger in the NW part where the Permian limestone comes in contact with it.

5. *Chutien fault*:—Parallel to the Kuanhsinting fault, there is another one at Chutien. The existence of this fault is proved by the cutting off of the Chiulaotung formation, bringing down the Yühsienssŭ shale in contact with the Sinian limestone, though the actual contact is not clearly shown. The throw is small with the down-throw side on the west.

6. *Omeishan major fault*:—The lofty cliff and the abrupt uplift of the mountain is undoubtedly due to the faulting. However the fault line is not closely along the cliff but it lies at the foot of the mountain. This can be seen on the road from Omei to Lungchih (龍池) (Fig. 6). It runs in the NE and SW direction with fault plane dipping to SE at rather high angle as has been observed at some locality southwest of Kaochiao (高橋). In the north eastern part it brings the Jurassic coal series down in contact with the Sinian limestone, while in the southwestern part the Jurassic coal series is in contact with both the Sinian limestone and the Palæozoic formations. This shows that the throw of the fault is somewhat variable, larger on the north-east and smaller on the southwest. Most probably this fault is younger than the Kuanhsinting and Chutien faults, the latter two seem to have been intersected by the former. This may be shown by the fact that the upthrow side of the Omeishan major fault is composed of high mountains which are affected by the Kuanhsinting and Chutien faults while the down-throw side comprises only low hills and small hillocks which appear to have not been disturbed by those faults.

Orogenic movement.

So far as we have observed in Omeishan the formations from the Sinian to the Cretaceous inclusive follow one by one either in conformable or in dis-

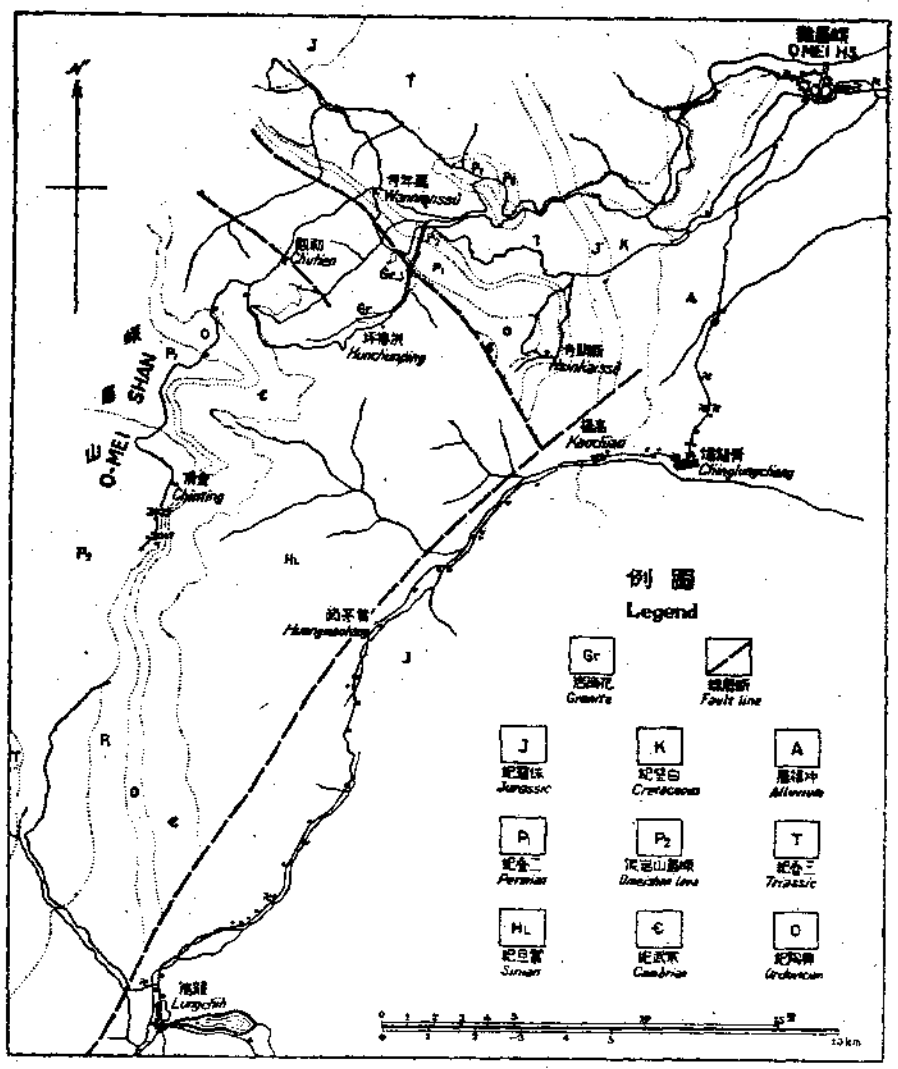


Fig. 6. Sketch map showing the faults of Omeishan.

conformable contact, though there exists a great hiatus in the middle palæozoic. This shows that no discernible orogenic movements corresponding to the Caledonian and Hercynian took place in this area. Neither indication has ever been found to prove the existence of the orogenic movement in the late Mesozoic corresponding to the Yenshanian which was prevalently pronounced in northern China. But Mr. Chao's belief in the Yenshanian[1] movement

1. Yatseng T. Chao, Geological Notes in Szechuan. Bull. Geol. Soc. China. Vol. VIII, No. 2, p. 144.

is due to his identification of the Feihsienkuan formation for the lower Cretaceous beds which were supposed to lie directly upon the Permian basalt and due to his everlooking the relation between the Cretaceous beds and the Jurassic coal series at Niangkou and at Kuanhsien in northern Szechuan.

In fact the Chiating formation, i. e. the middle part of the Red Beds which is probably of middle Cretaceous age has undergone strong folding as shown at Niangkou, and the Cretaceous beds were continuously deposited upon the Jurassic sediments without any noticeable break between. It is evident that the date of the orogenic movement was post-Cretaceous or at least later than the age of the Chiating formation. Furthermore at other localities in western Szechuan the Mengshan formation, i. e., the upper part of Red Beds is also known to have been folded to form anticlines and synclines with inclination up to over 60 degrees. The Mengshan formation is regarded as belonging to the upper Cretaceous, thus the folding is probably posterior to the Upper Cretaceous. Thus we assign the orogenic movement to the Himalayan rather than to the Yenshanian.

PHYSIOGRAPHY

Omeishan stands at incomparable elevation with the surrounding mountains on the border of the red basin and shows the precipitous cliffs, narrow gorges, and water falls which are typical of the youthful stage of erosion. The general topography is shown on the contour map. The drainage in the surveyed area is composed of three principal streams, they are that passing through the Lungmentung gorge, that passing by Chinglungchang and the Huchi running before Fuhussŭ.

The Lungmentung river has two sources, one coming from Chiulaotung, passing through Hungchunp'ing valley and reaching Chingyinko, and the other from Yühsienssŭ passing through Shihhsunkou and meeting the former below Shuangfeichiao at Chingyinko. The two streams are nearly parallel to each other, flowing from southwest to northeast and cutting the valleys in the Sinian limestone. On account of the gently inclined strata with plenty of vertical joints the erosion often results in steep cliffs and pinnacle-like peaks from which the name Shihhsunkou—"Stalagmite valley"—is derived. In the vicinity of Heilungchiang the Permian limestone somewhat similar to the

Sinian limestone in characters forms the narrow gorge with a moderate depth. From the sources down to the junction the distance is not more than 5 km., the difference of elevations reaches 900 m. Thus the small rapids and waterfalls are frequently met with. Below the junction of the two streams the rocks on both sides of the river are the Feihsienkuan purple sandstone and shale, in which the wide and gentle valley is developed. Down to Niupeishan it turns to north and receives the water which comes from Loukou cutting the Chialingchiang limestone to form the Chiping gorge. After combining with the tributary from Kungpeishan this stream passes through the area of the Feihsienkuan sandstone and shale and enters the former river at Niupeishan. Crossing the Watuanshan anticline and going to east the stream runs almost in the direction normal to the strike of the strata, thus the valley is usually deep and steep, especially at Lungmentung gorge, where the Chialingchiang limestone stands vertically, forming the gate of Omeishan. On the east of Lungmentung the hills become lower and gentler and the river meanders to east unlike that in the mountain.

The stream which passes through Chinglungchang has its source below the lofty cliff, flowing to east and cutting the valley in the Sinian limestone and occasionally in granite in which the narrow gorges and waterfalls are not uncommon. After coming out from the mountainous region and receiving the tributaries it runs northeastward and then turns to east. The rock boulders spread on the river bed are very large, this indicates that the stream has a high grade of inclination often with heavy floods.

The stream Huchi comes from Leitap'o and flows below Leiyinssŭ and Fuhussŭ eastward to the plain. It also cuts the strata to form the small gorges and waterfalls, such as at Kaotungkou in the Permian Limestone and below Leiyinssŭ in the Triassic limestone.

In dealing with the relation of the lithologic characters to topographic features, the limestone is the harder rock in this region, giving rise to deep valleys and narrow gorges. There are four kinds of limestone, namely, Sinian, Cambrian, Permian and Triassic limestone. Nearly every precipitous feature is resulted from one of them. The granite is also a hard rock, but the outcrops are low and little, giving no much influence on the topography. The Lower Palæozoic strata were uplifted to higher position by faults, thus forming the constituents of steep cliffs. Basalt is also another hard rock, capping on the top of the mountain and forming the upper part of the Omeishan big cliff. When it occurs in valley, gorges are also often found. The soft rocks are the shales and clays and some sandstones of the Feihsienkuan formation, the Hsiang'chi series and the Cretaceous formations, which form rather broad valleys. But owing to the high grade of the river bed the down-cutting is still predominant until the plain is reached.

The geological structure has intimate relationship to the development of the drainage. When the Omeishan anticline has been formed there were some consequent streams on both limbs, flowing down along the dipping direction. Those on the western limb of the anticline were not visited, while those on the eastern limb can be traced in the area here concerned. Since at that time the Kuanhsinting fault has not occured, the Watuanshan anticline was not so prominent, and the Mesozoic formations have not suffered pronounced erosion, the surface was a gentle slope, on which the streams were not much prevented. Subsequently the eastern limb was affected by the Kuanhsinting fault, a larger part sinking down to form down-throw side with the strata to be more folded and uplifted, but the river courses have already been formed in which the down-cutting continued to result in steep valleys and narrow gorges. On the other hand the streams cut the valley head-ward and have crossed the axis of the big anticline. Although the western limb was affected by the Chutien fault, it was still much higher than the eastern limb, thus the streams could not directly work to Changlaop'ing and Chutien but extended to Chiulaotung, Yühsienssŭ and Kungpeishan along the courses to which the structural features as well as the rock characters were suitable for the invading and down-cutting of the streams.

The river which flows before Chinglungchang, has grown up under the similar condition as mentioned above. At first the streams had their courses on the eastern limb of the major anticline lying in about southeast direction. After the big fault had happened, along the fault scarps was formed a new river valley receiving the waters from the west. The head-ward cutting of the streams extended across the fault scarps and reached the present place below the Omeishan cliff. Along the upper course the strata are nearly horizontal or gently inclined, so the precipitous cliffs and narrow gorges are formed. (Fig. 7).

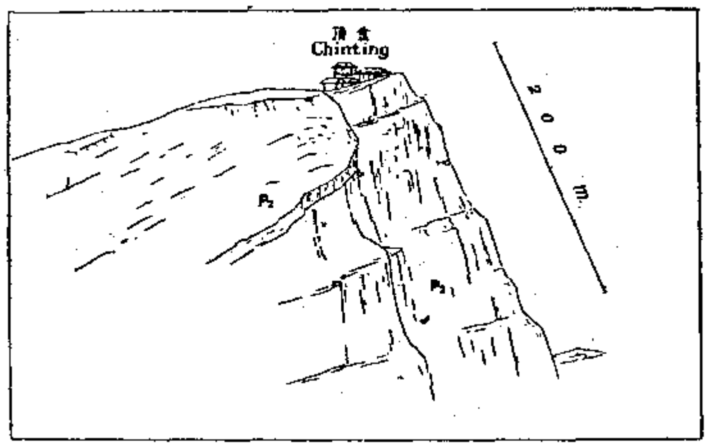
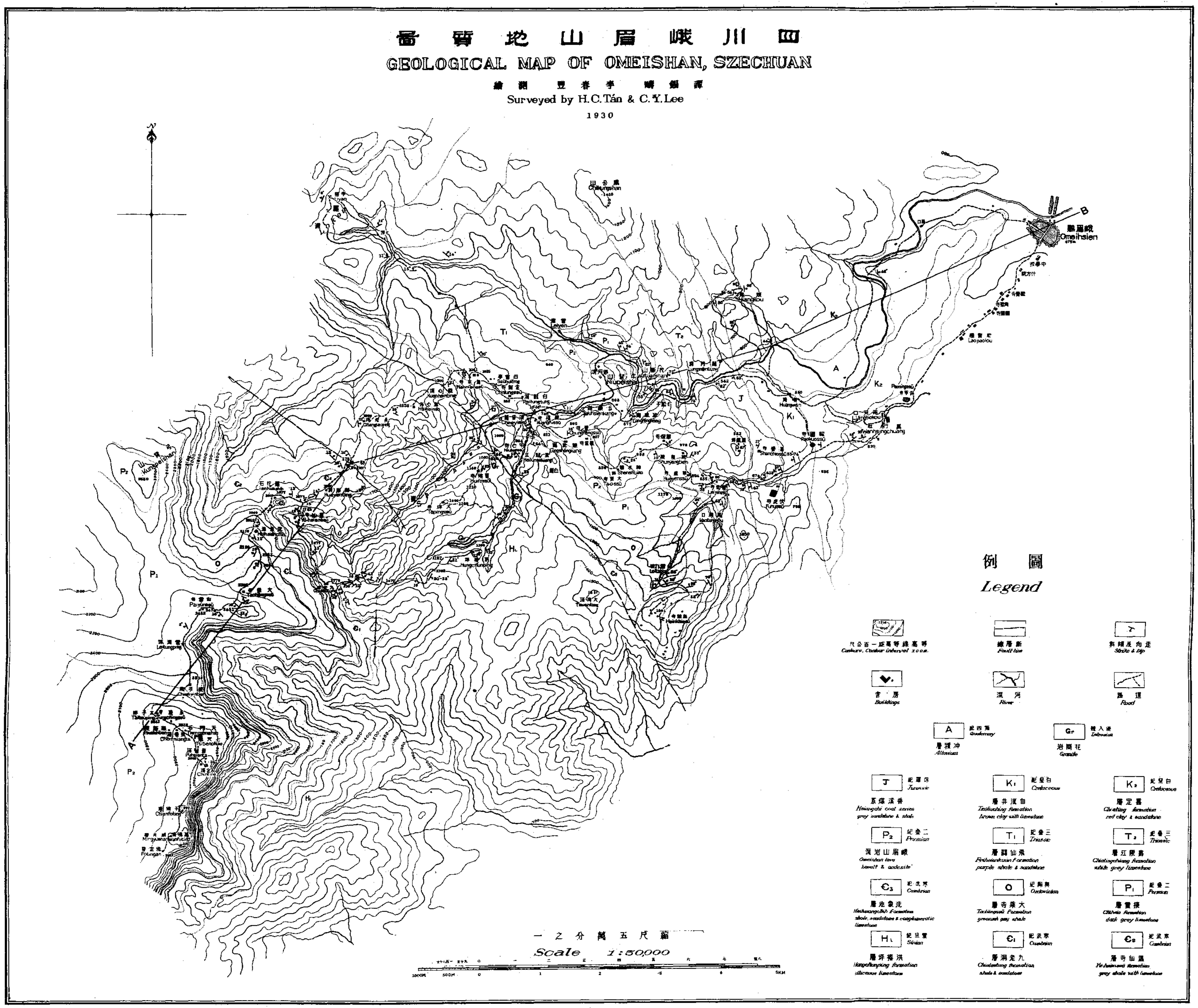


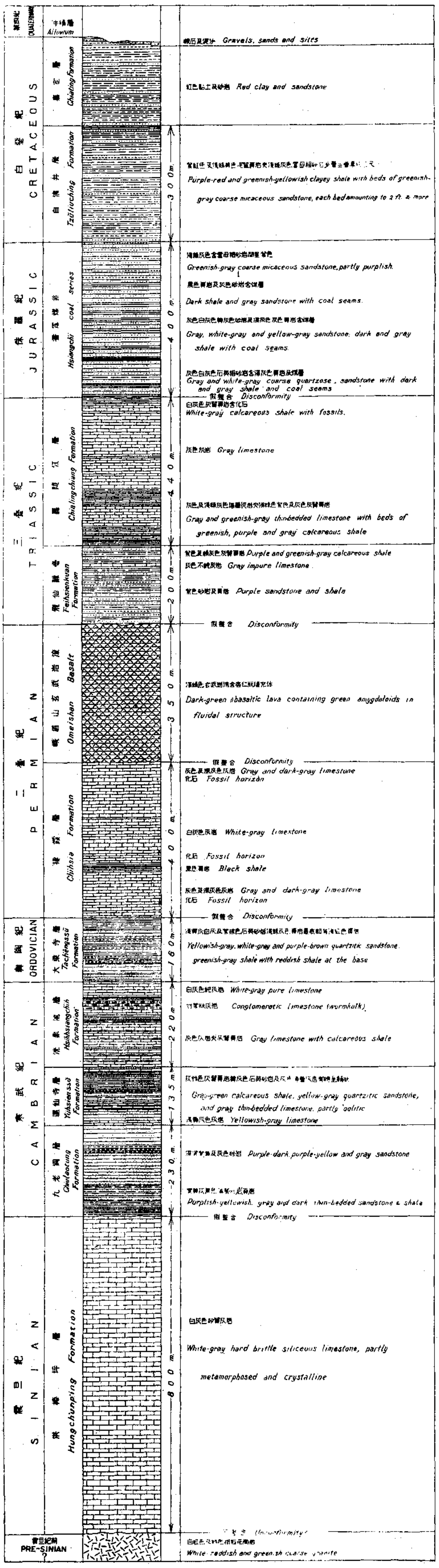
Fig. 7. Diagram showing the gentle slope of the top and the preciptious cliff of Omeishan.

The river Huchi might have been developed simultaneously with the Lungmentung river but has not been affected by the fault.



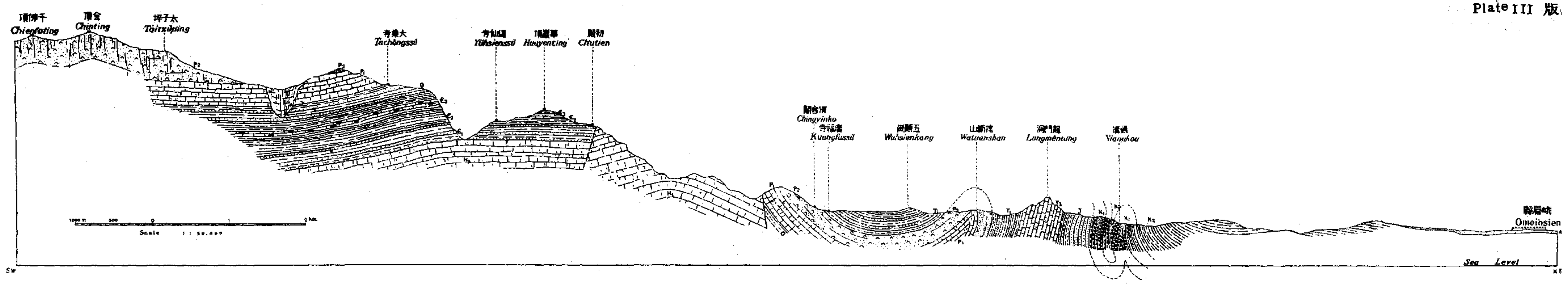
四川峨眉山地質圖
GEOLOGICAL MAP OF OMEISHAN, SZECHUAN
譚錫疇 李春昱 測繪
Surveyed by H.C.Tán & C.Y.Lee
1930
Omeihsien
圖例
Legend
等高線 等高距一百公尺
Contours, Contour interval 100 m.
斷層線
Fault line
走向及傾斜
Strike & Dip
房舍
Buildings
河流
River
道路
Road
A 第四紀 Quaternary
冲積層 Alluvium
Gr 侵入體 Intrusion
花崗岩 Granite
J 侏羅紀 Jurassic
香溪煤系 Hsiangchi coal series gray sandstone & shale
K1 白堊紀 Cretaceous
自流井層 Tzeliuching formation brown clay with limestone
K2 白堊紀 Cretaceous
嘉定層 Chiating formation red clay & sandstone
P2 二疊紀 Permian
峨眉山岩流 Omeishan lava basalt & andesite
T1 三疊紀 Triassic
飛仙關層 Feihsienkuan Formation purple shale & sandstone
T2 三疊紀 Triassic
嘉陵江層 Chialingchiang formation white gray limestone
Є3 寒武紀 Cambrian
洗象池層 Hsihsiangchih Formation shale, sandstone & conglomeratic limestone
O 奧陶紀 Ordovician
大乘寺層 Tachengssu Formation greenish gray shale
P1 二疊紀 Permian
棲霞層 Chihsia Formation dark gray limestone
H1 震旦紀 Sinian
洪椿坪層 Hungchunping formation siliceous limestone
Є1 寒武紀 Cambrian
九老洞層 Chiulaotung formation shale & sandstone
Є2 寒武紀 Cambrian
遇仙寺層 Yühsienssu formation gray shale with limestone
縮尺五萬分之一
Scale 1:50,000

四川峨眉山地層柱狀圖
A GENERALIZED COLUMNAR SECTION
Showing the
STRATIGRAPHY of OMEISHAN, SZECHUAN.

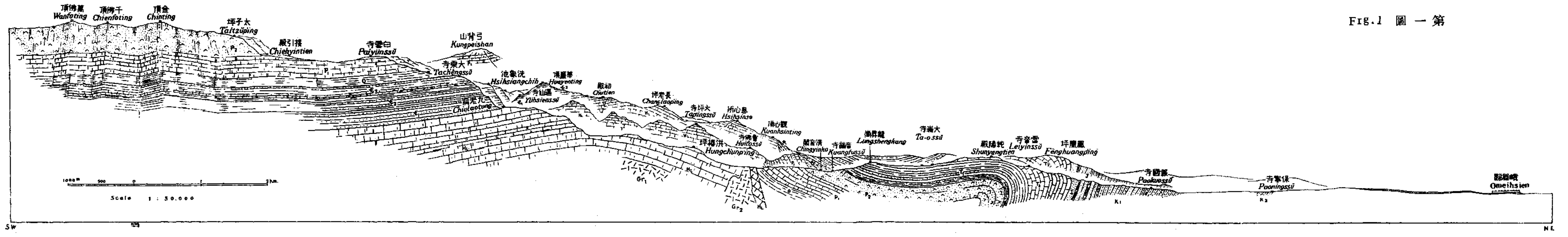


四川峨眉山地質剖面圖

Plate III 第三版



第一圖 Fig. 1



第二圖 Fig. 2

Fig. 1 General section showing the formations and structure of Omeishan.

Fig. 2 General section showing the formations, structure and intrusion of Omeishan. Gr_1, Pre-Sinian granite; Hl, Sinian Hungchunp'ing limestone; ϵ_1, Cambrian Chiulaotung formation, shale and sandstone; ϵ_2, Yühsienssu formation, gray shale and sandstone with limestone; ϵ_3, Hsihsiangchih formation, shale, sandstone and conglomeratic limestone; O, Ordovician Tachengssu formation, yellowish gray shale and sandstone; P_1, Permian Chihsia formation, dark-gray limestone; P_2, Omeishan basaltic lava; T_1, Triassic Feihsienkuan formation, purple sandstone and shale; T_2, Chialingchiang formation, white-gray limestone; J, Jurassic Hsiangch'i coal series, gray sandstone and shale; K_1, Cretaceous Tzuliuching formation, purple brown clay and sandstone; K_2, Chiating formation, red clay and sandstone; A, Quaternary gravels, sands and silts; Gr_2, Granite intrusion.

第一圖　峨眉山地層及地質構造剖面圖（沿AB線）

第二圖　峨眉山地層及地質構造剖面圖內有火成岩侵入體（沿小路線）Gr_1, 震旦紀前花崗岩；Hl, 震旦紀洪椿坪灰岩；ϵ_1, 寒武紀九老洞層—頁岩及砂岩；ϵ_2, 遇仙寺層——灰色頁岩砂岩夾灰岩，ϵ_3, 洗象池層——頁岩，砂岩，及竹葉狀灰岩；O, 奧陶紀大乘寺層——黃灰色頁岩,砂岩，P_1, 二叠紀棲霞層——深灰色灰岩；P_2, 峨眉山玄武岩流；T_1, 三叠紀飛仙關層—紫色砂岩及頁岩；T_2, 嘉陵江層——白灰色灰岩；J, 侏羅紀香溪煤系——灰色砂岩及頁岩；K_1, 白堊紀自流井層——紫棕色黏土及砂岩；K_2, 嘉定層——紅色黏土及砂岩；A, 第四紀礫石層及沙土；Gr_2, 侵入花崗岩.

第一圖 峨眉山千佛頂在絕崖上山頂坡面向西傾斜

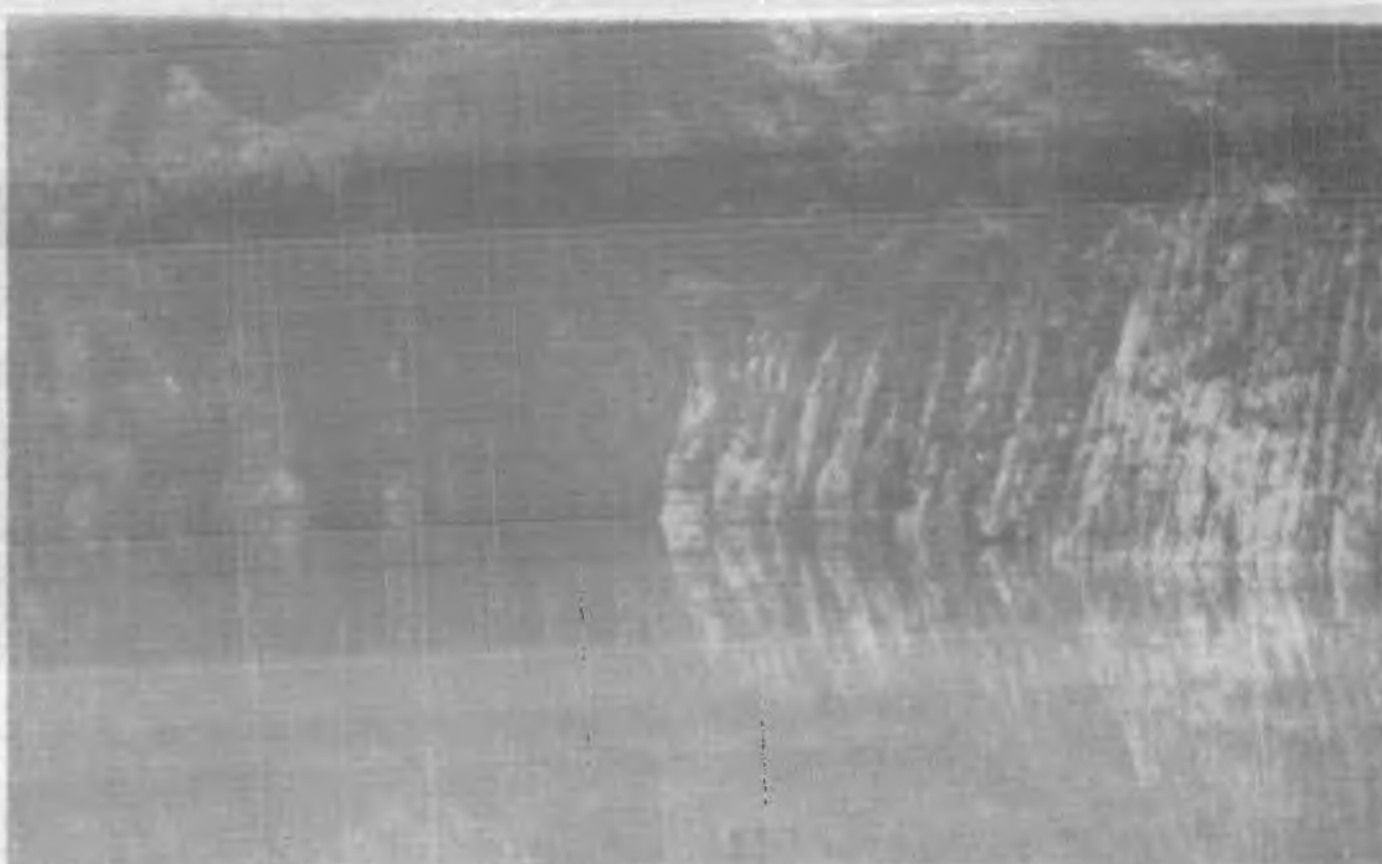
Fig. 1. Chienfoting on the cliff and the top of the mountain Omeishan sloping to west.

第二圖 峨眉高橋附近青龍場河巨石滿佈

Fig. 2. Big boulders spread on the bed of the Chinglungchang river at Kaochiao, Omeihsien.

第三圖　峨眉山白雲寺南二叠紀灰岩絕壁

Fig. 3. Cliff formed of Permian limestone at Paiyunssu on Omeishan.



第四圖　峨眉山龍門洞三叠紀灰岩層成直立

Fig. 4. Vertical bedding of Triassic limestone at Lungmentung in Omeishan.

第五圖 峨眉山清音閣黑龍江二叠紀灰岩峽谷上有木橋

Fig. 5. Heilungchiang gorge in Permian limestone with board bridge on the south of Chingyinko in Omeishan.

第六圖 峨眉山龍門洞三叠紀灰岩峽谷

Fig. 6. Lungmentung gorge in Triassic limestone at Lungmentung in Omeishan.

第七圖 峨眉山伏虎寺西三叠紀灰岩瀑布

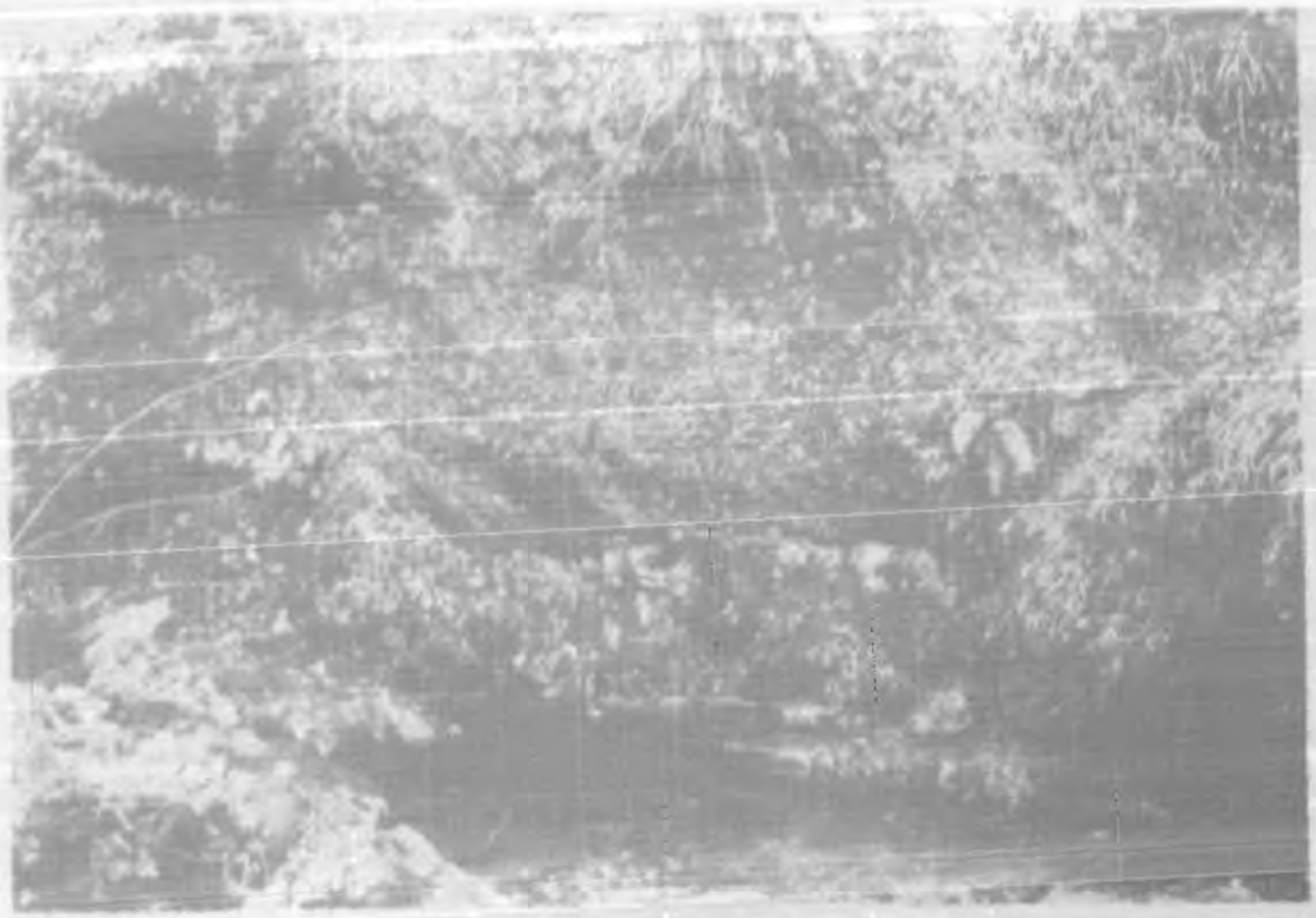
Fig. 7. Waterfall in Triassic limestone on the west of Fuhussu in Omeishan.

第八圖 峨眉山清音閣雙飛橋下峽谷沿玄武岩流裂隙而生

Fig. 8. Small gorge cut along the fissure in basaltic flow below Shuangfeichiao at Chingyinko in Omeishan

第九圖 峨眉山金頂下玄武岩柱狀構造

Fig. 9, Columnar structure of the basalt at the cliff below Chinting on Omeishan



第十圖 峨眉山九老洞北羅鍋崖震旦紀灰岩及寒武紀九老洞層之接觸

Fig. 10, Disconformable contact between Sinian limestone and Cambrian Chiulaotung formation at Luokuoyai north of Chiulaotung in Omeishan

第十一圖 峨眉山西雲佈似海山嶺露出狀如島嶼

Fig. 11. Cloud sea with island-like mountain tops and ridges viewed westward from the top of Omeishan

第十二圖 峨眉山金頂下玄武岩絕壁

Fig. 12. Basalt cliff below Chinting on Omeishan.

第十三圖 峨眉山萬佛頂下玄武岩絕壁及雲海

Fig. 13. Basalt cliff and cloud sea below Wanfoting on Omeishan.

THE HYDROGEN-ION CONCENTRATION OF CLAYS AND THEIR EFFICIENCY AS DEHYDRATION CATALYSTS.§

BY

E. O. WILSON AND C. Y. LIN

It is generally believed that the hydrogen-ion concentration of clays and soils is important from an agricultural point of view. It has also been stated that the acidity of clays has a significant relation to their absorbtive and catalytic properties. Many Fuller's earths which have been found valuable for bleaching purposes show a distinct "acid reaction." "If a sample is touched to neutral litmus paper the paper will be turned red; if the clay is suspended in water and phenolphthalein is added, a quantity of alkali, which varies with different earths, can be added before the red color appears. The same power that enables the earth to absorb basic colors enables it to absorb true base also."[1] Certain Japanese earths and clays such as Kambara earth which are largely used as decolorizing agents and for catalytic purposes have been characterized by K. Kobayashi[2] as "acid earths" to distinguish them from ordinary kaolin and clay. The term "acidity" as used by the above investigators refers to the ability of the clay to absorb base rather than to the effective hydrogen-ion concentration of an aqueous suspension of the clay.

In the present investigation the pH values of 36 Chinese clays were determined as a preliminary study. A study of the catalytic properties and decolorizing efficiency of these and other clays is now under way. In this work the pH values were determined with a hydrogen electrode and with a quinhydrone electrode. There seems to be a difference of opinion regarding the reliability of the quinhydrone electrode for the determination of the pH values of clay suspensions, some investigators obtaining results which check with determinations on the same clays by other methods[3] while others report variable and unreliable results with the quinhydrone electrode[4].

It is known that kaolin and certain clays may be used as catalysts for the production of ethylene from ethyl alcohol. Just what property of the clay

§ Contribution from the Chemical Department of the Yenching University.

1. Fuller's Earth, by, C. L. Parsons, Bull. 71. Mineral Technology, Department of Interior. U. S. Bureau of Mines.
2. The Kambara Earth, Kobayashi, Jour. Ind. Eng. Chem. 4. 12.
3. Jour. Agricultural Research, 35, 825.

is responsible for this catalytic action is unknown. The fact that the Kambara earth is such an efficient catalyst for this reaction suggested that there might be some relation between the acidity of the clay and its catalytic property. Preliminary experiments were conducted using four clays of different pH values ranging from 4 to 6.4. The volume percent of ethylene in the gaseous phase obtained by passing alcohol vapor over the heated clay was taken as a measure of the relative efficiency of the catalyst.

EXPERIMENTAL PROCEDURE.

A. For the determination of hydrogen-ion concentration.

The technique followed in measuring the hydrogen-ion concentration was very similar to that used by R. H. Bray[4] of the Illinois Agricultural Experiment Station.

The electrode vessel is a Gooch funnel with the stem bent up and a perforated porcelain plate sealed in the bottom. The hydrogen enters the tube bubbles up through the plate to the electrode and escapes from above. The electrode is a piece of platinum wire about 3 cm. long sealed into the end of a glass tube. Mercury was used in the glass tube for making the necessary electrical contact. The platinum wire was plated with palladium black (preliminary experiments with electrodes plated with platinum black showed that such electrodes were quickly spoiled, possibly because of the abrassive action of the clay particles in the agitated suspension). The palladium coated electrodes proved very satisfactory. Standard buffer solutions were used as a check after each reading.

A normal calomel electrode was used and the voltage was measured by a Leeds and Northrup portable potentiometer.

Twenty c. c. of distilled water were introduced into the electrode vessel and the hydrogen allowed to bubble through. Eight grams of soil were then added and the electrode inserted. The bubbling was continued for about 15 minutes, after which connection was made to the calomel electrode.

The potential reading was taken when it had become constant for about 5 minutes.

4. Jour. Ind. Eng. Chem., 20, 4, 421.

A similar procedure was used for the determinations with the quinhydrone electrode. The electrode used was a gold plated platinum wire of the usual design. Sufficient quinhydrone was added to saturate the solution.

B. Efficiency as catalysts for the dehydration of ethyl alcohol. The apparatus was set up as shown in figure 1.

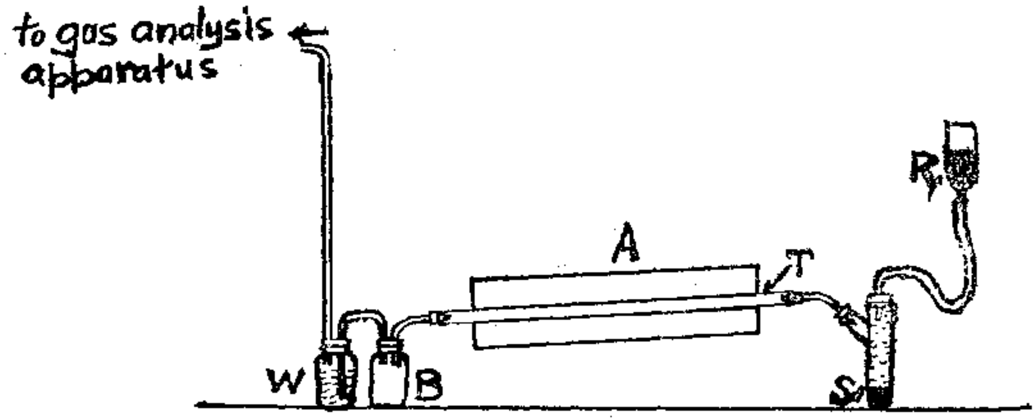


Fig. 1

A is a combustion furnace. *T* a Pyrex combustion tube about 1 cm. in diameter by 100 cm. in length. One end of the furnace was raised slightly so that the tube was in a slanting position. The higher end of the combustion tube was connected through a glass side arm with the tube *S* as shown. The top of tube *S* was closed by a one-hole rubber stopper carrying a short glass tube drawn to capillary dimensions at its lower end and attached to the reservoir *R* by means of rubber tubing. At the other end of the combustion tube is attached a safety bottle *B* and a wash bottle *W*, partly filled with water for collecting the condensed vapors of unchanged alcohol, and for dissolving the acetaldehyde. The temperature of the furnace was determined by means of a calibrated Chromel-Alumel thermocouple. The alcohol was fed slowly into the furnace by allowing the mercury to flow from the reservoir *R* through the glass tube into the test tube *S*, which was filled with alcohol. After having allowed the reaction to proceed at a constant temperature for a few minutes a sample of the gas was collected in the gas analysis apparatus over a strong sodium chloride solution. The sample of gas was allowed to come to room temperature and adjusted to a volume 100 c. c. at barometric pressure. Ethylene was determined by absorbtion in bromine water and the decrease in volume noted after absorbing the bromine vapor in sodium hydroxide solution.

RESULTS.

Old Samples

No.	Name	Place of Production	*pH Value* Hydrogen Electrode	Quinhydrone Electrode
1	Kaolinite 高嶺土	安徽祁門縣大北港	4.27	4.75
2	Kaolinite (brick form)	江西萍鄉	4.96	5.30
2E.		Tangshan 唐山	5.16	5.88
3G.S.		河南武安縣彭城	5.56	5.88
4G.S.		山西襄垣上豐村南灣	8.25	6.90
5G.S.		河北灤縣唐山	7.49	6.62
6G.		Tangshan 唐山	5.82	6.54
7G.S.		山東博山縣山頭村	7.04	6.53
	Bowl clay		3.98	4.51
8G.S.		山東淄川范家村	5.38	6.16
B	Jar clay		5.47	7.20
4F.		Tangshan 唐山	5.78	6.93
D	Banbidian clay	半壁店土	6.43	6.30
H		Yentai 煙台	5.48	6.66
6G.S.		山西平定縣蔭營村	5.66	6.13
		New Samples (from Geological Survey)		
1	Fire clay	磁縣彭城	5.87	7.20
2	White clay	磁縣馬家庄	5.44	6.72
3	” ”	磁縣彭城	5.33	7.20
4		彭城北八里馬家庄	5.12	5.83
5		磁縣西佐西北西漢	5.18	7.20
6	缸土	磁縣蔺家庄	5.77	6.31

No.	Name	Place of Production	*pH Value* Hydrogen Electrode	*pH Value* Quinhydrone Electrode
7	缸土	磁縣彭城溝河下	5.44	6.91
8		磁縣彭城	3.66	4.43
9	砂鍋土	彭城北十五里下枝劍	4.94	6.54
10	Clay (Dark grey)	彭城北八里馬家庄	4.21	4.95
11	” ” ”	磁縣彭城	3.64	4.29
12	白堿	彭 城	5.09	6.81
13		彭城北五里南羊台	4.48	7.20
14		磁 縣 彭 城	5.51	5.84
15	Purified clay 堿	” ” ” ”	5.52	>7.20
16	Shale 砂子	” ” ” ”	5.56	6.55
17	” 鵝鵠翎	磁縣張家樓	5.12	6.39
18	For Glaze 堿彩	磁 縣 彭 城	6.83	>7.20
19	” ” 白堿	” ” ” ” 所用	7.11	>7.20
20	Purified 細黑釉 loessic clay	磁 縣 彭 城	7.47	>7.20
21	Loessic clay 作黑釉之黃	” ” ” ”	5.64	>7.20*

*The readings > 7.20 are given for cases where the voltage was negative and a precise determination of the pH was not obtained by means of the quinhydrone electrode.

DISCUSSION OF RESULTS.

When platinum chloride solution was used to plate the electrode the life of the electrode was very short. The electrode thus plated could only be used at most for two determinations and also the results were often very peculiar. Sometimes the electrode was spoiled before a constant reading could be obtained. The spoiling of the electrode was indicated by a continuous decrease of the potential. The life of the electrode depended on the nature of the clay sample used. Bowl clay spoiled no electrode and the reading was also very constant and accurate, four different determinations using different electrodes gave the same potential difference. This was not the case with other clays. The real cause of spoiling is not well understood. The probable explanation is that the colloidal substance of the clay adhères to the electrode and at the same time the platinum black is worn off by the coarse particles. But it is not easy to explain why the life of the electrode plated with palladium chloride solution was so long. One electrode could be used for thirteen determinations.

The pH value determined by the quinhydrone electrode was greater than that determined by the hydrogen electrode but with exceptions. In some causes the potential difference was negative. This might due to the unknown reactions between quinhydrone and organic substance in the clay.

In order to find out whether or not there exists any relation between "acidity" and efficiency as a dehydrating catalyst, four clays having high pH values and four having low pH value were studied. The results show that the catalytic property has nothing to do with the acidity. The four clays of pH value from 3.66 to 6.43 gave very high percentages of C_2H_4 gas. This might be due to the fact that the four clays contain many kinds of oxides the mixture of which is a better catalyst than a single one. High kaolin content might also account for the results, because it has been pointed out that kaolin makes a good catalyst for the dehydration of alcohol.

SUMMARY.

1. The hydrogen-ion concentrations of 36 clays were determined with a hydrogen electrode and a quinhydrone electrode.

2. Hydrogen electrodes plated with platinum black were spoiled very easily while electrodes plated with palladium black could be used for thirteen determinations.

3. Four clays of high pH value and four of low pH value were used as catalytic agents for the dehydration of ethyl alcohol. All the clays gave a very high percentage of C_2H_4 gas. No relation exists between "acidity" and dehydrating property.

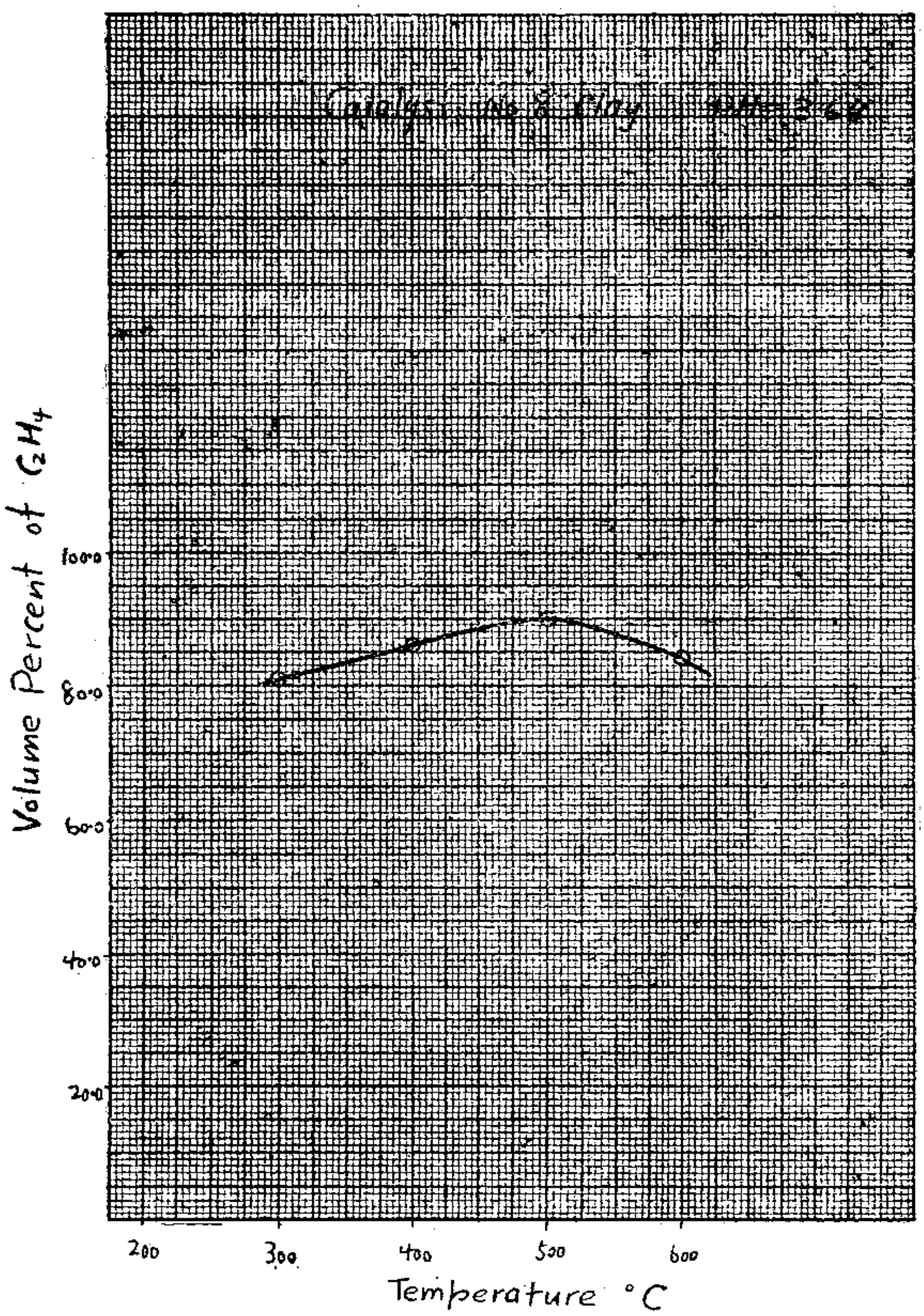

Volume Percent of C_2H_4
100.0
80.0
60.0
40.0
20.0
200
300
400
500
600
Temperature °C

Fig. 1.

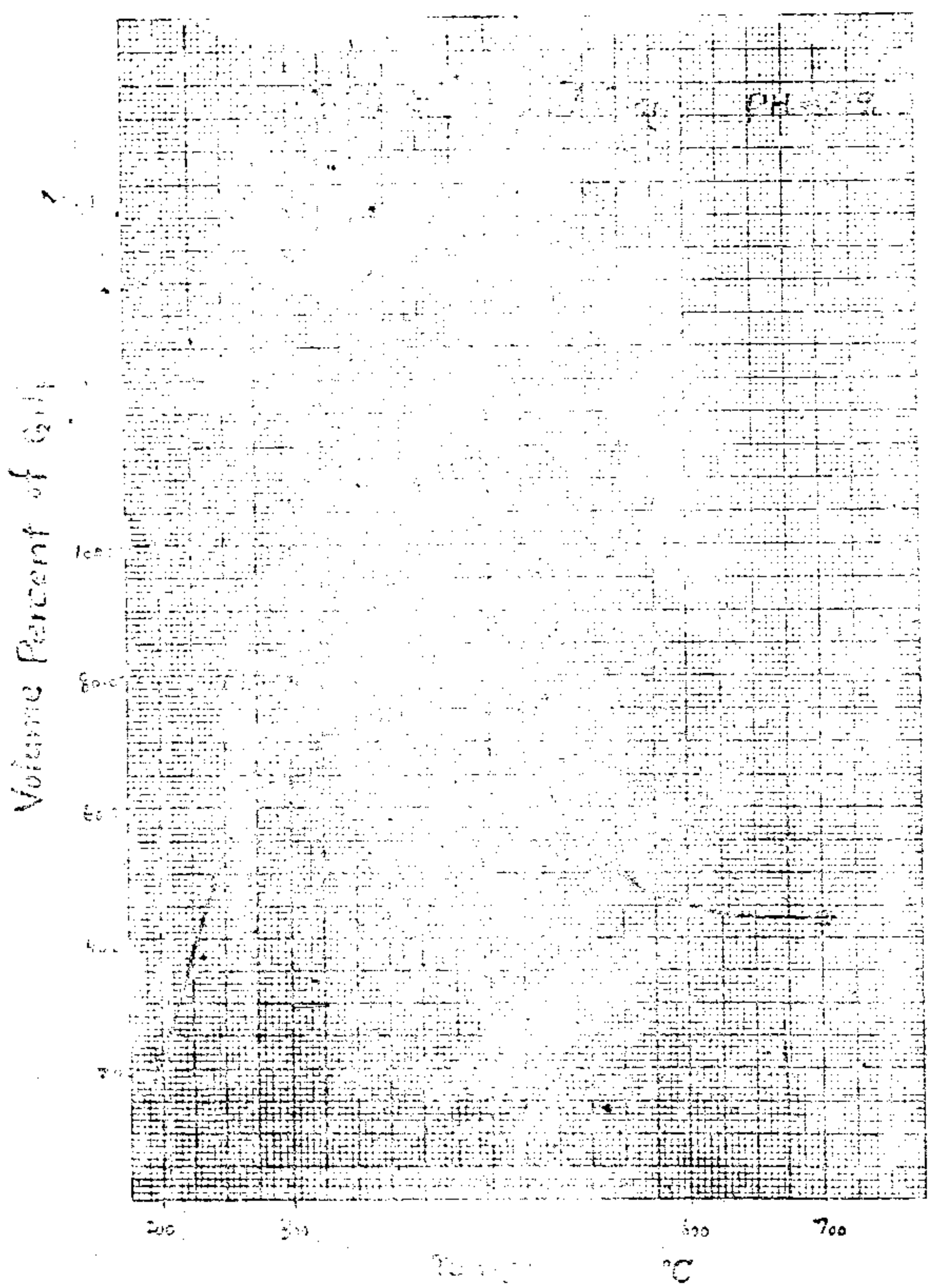


Fig. 2.

Catalyst.

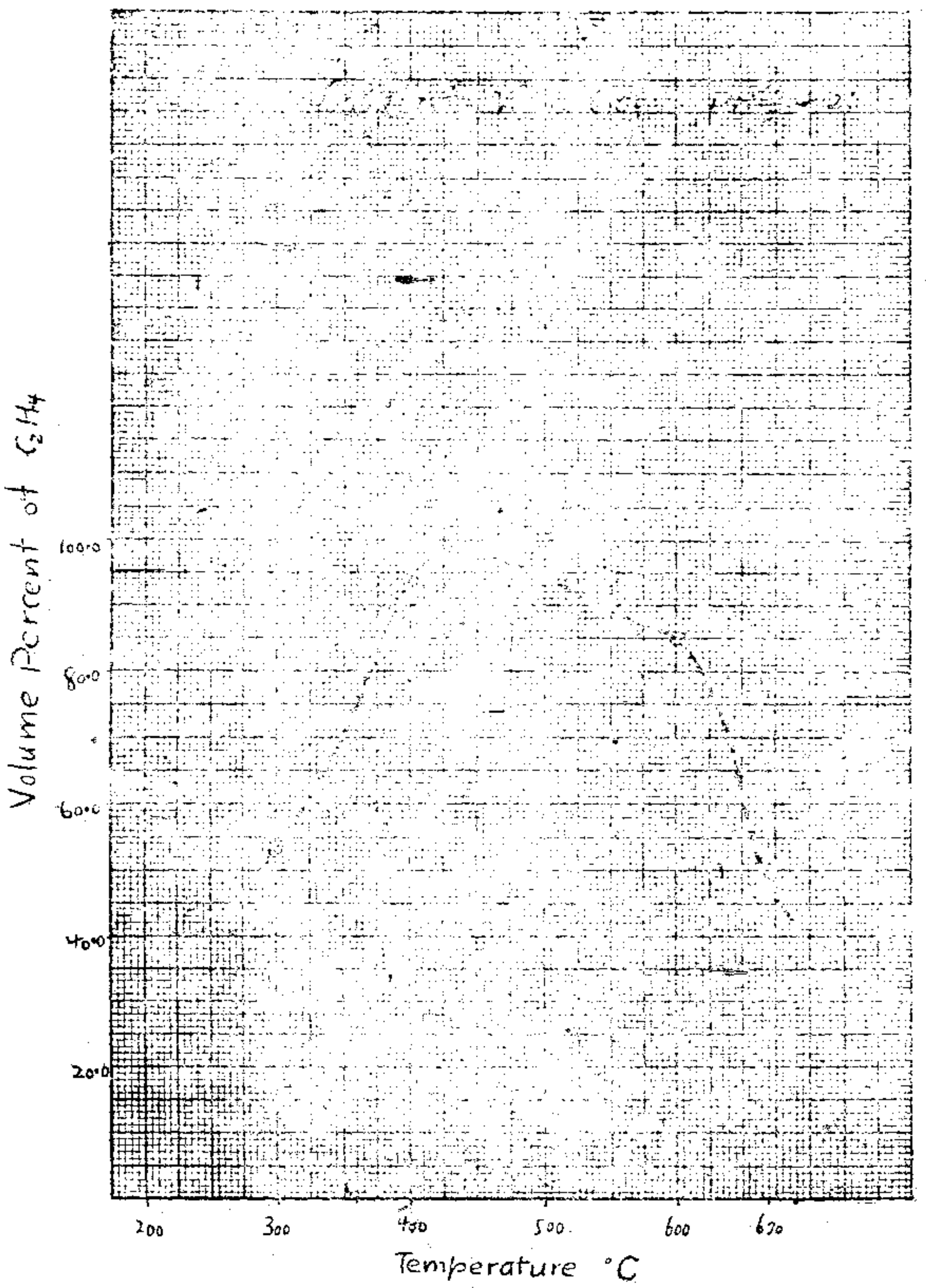


Fig. 3.

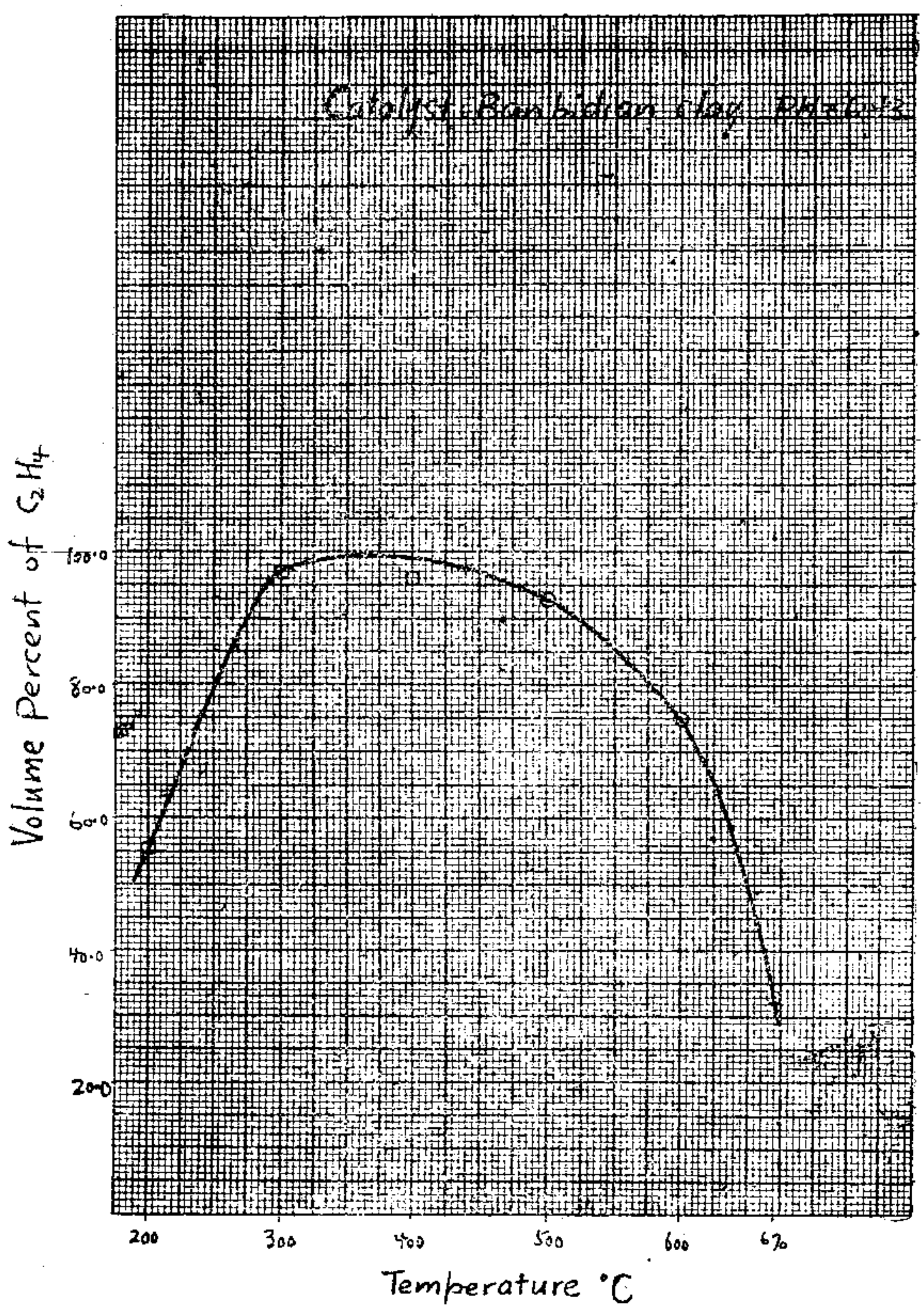

Volume Percent of C_2H_4
100·0
80·0
60·0
40·0
20·0
200
300
400
500
600
670
Temperature °C

Fig. 4.

ON THE OIL GEOLOGY OF NORTH SHENSI.

BY C. C. WANG

WITH THE ASSISTANCE OF C. H. PAN.

INTRODUCTION.

The first trip[1] made by the author in North Shensi was in 1923 when he travelled from Fukuhsien, an important city at the northeast corner of north Shensi, southwestward across Yulin to Chingpienhsien, and thence eastward through Suite city to Wupuhsien on the right bank of the Yellow River. As a result of that trip, the so-called Shensi series considered to be of Carboniferous age by American oil geologists such as F. G. Clapp and M. L. Fuller, was proved by the find of a number of plant fossils to be really Lower Jurassic. Also the Anting limestone which the named authors' formerly assigned to Permian age was found to be uppermost Jurassic as proved by the discovery of ganoid fishes in that limestone horizon.

In the Summer of 1932, for the purpose of studying the oil geology, the author undertook another trip in north Shensi over a wide area including the districts of Wupu, Chingchien, Anting, Fushih, Yenchang and Yenchuan. The nature of this trip was, however, also a reconnaissance work, since only twenty days were really spent for field survey.

It was at first intended to make a route map by a plane table and pacing in order to plot all the geological observations met with on the way. But, as the reconnaissance route maps by American oil geologists on the scale of 1 to 211,200 and the 1 to 100,000 topographic sheet of the General Staff maps, were found to be accurate enough for the author's purpose, they were used as base for geologic study through the whole trip.

In the field besides investigating the lithological characters of the oil bearing sediments and their geologic structures special attention was paid to study the oil seepages and their geological position. Numerous plant fossils have been collected from different horizons so as to give some better idea of

1. C. C. Wang: On the Stratigraphy of North Shensi, Bull. Geol. Soc. China, Vol. 4, No. 1, 1925.

the geological age of the successive formations. Further, the discovery of oil shale gives some new economic significance.

General Geology.

The North Shensi stratigraphy was first studied in some detail by American geologists F. G. Clapp, M. L. Fuller and others during 1914-1915, and was classified by them as follows in descending order:

1. Shansi series, gray sandstones and shales with coals.
2. Fenho series, red sandstone.
3. Shensi series, gray sandstone and shale with thin coals and oil-bearing.

(1–3: Carboniferous)

4. Red-shale, sandstone and thin bedded limestone of Permian age.
5. Red sandstone, Fermo-Mesozoic.

The above geological ages are all based on their unpublished reports now in possession of the Geological Survey of China. In 1922 basing on the fossils collected in north Shansi the author reclassified the sediments above the Shansi and Fenho series of the American geologists into the following four series:[1]

I. The Lower Jurassic (Liassic) coal series. (about equivalent to Shensi series).

II. The red shale and sandstone, probably of Middle or Upper Jurassic age.

III. The shaly limestone, Upper Jurassic.

IV. The red cross-bedded sandstone, possibly of Uppermost Jurassic to Cretaceous age.

As oil is mainly contained in the Lower Jurassic coal series, the present paper chiefly treats of this series in regard to its oil bearing horizons and the oil seepages along its exposures. In order to get a general idea for such facts a detailed description of sections along the routes is necessary.

1. These divisions were adopted in the main by Messrs. Fuller and Clapp in their later papers published in America.

DESCRIPTION OF ROUTES.

Before describing the sections, the general topographic feature of north Shensi should be stated first. It constitutes a dissected plateau at the average height of 3500 to 4000 ft. above sea level with surviving relief of about 500 ft. The rock formations consist mostly of Mesozoic sediments thickly covered by Cenozoic deposits of red clay and loess. If one stands on a summit of the hills near the Yellow River he may notice the whole view of the plateau surrounded on the east in Shansi by high rocky ridges barely exposed. Such rocky ridges are generally composed of Cambro-Ordovician limestone constituting the base of the plateau-making sediments. Hence, to describe sections in the plateau the sediments just above the limestone base seem to be best selected as a starting point. In view of this fact, Liulinchen west of Lishihsien, Shansi, is chosen as the east suitable starting place.

Liulinchen to Wupuhsien: Liulinchen is situated just on the east margin of the north Shensi plateau or in other words it is located on the Permo-Carboniferous coal series gently dipping towards the west. From here westward to Wupuhsien there may be distinguished three rock series, at first dominant yellow greenish shales, then dominant red shale with thin reddish sandstone, and finally dominant red sandstone with thin red shale. From the first two series the author collected numerous plant fossils at Paotechow about 180 km. north of Liulinchen during 1920 sufficiently to prove their geological ages belonging to Permian and Permo-Triassic respectively. The last series may still be divided into two portions. The sandstone of its lower portion is composed mostly of quartz grains while that of the upper one near the valley of the Yellow River chiefly of feldspar i. e. it is really arkose sandstone The geological age of this series is provisionally assigned to Triassic. There is a good motor road between Liulinchen and Wupuhsien though no motor car is in engagement during the author's visit for the road east of Liulinchen has been partly destroyed by rain flood.

Wupuhsien to Chingchienhsien: The city of Wupuhsien is built on a high cliff on the west bank of the canyon-like valley of the Yellow River. During the summer the people living in the city may clearly hear the howling noise of the running water of the river. There are only about forty families in the whole city: The main route from Yulin to Taiyuan is about ten li south of the city where is located a large village called Sungchiachuan. From this village to Chingchienhsien there are two alternative routes; one is westward across Ihochen to Suitehsien and thence southward to Chingchienhsien at a total distance of about 240 li, the other is southwestward across Tsaolingp'ing and Tientzukou at a distance of 200 li. The former is much better and easier than the latter. The author travelled neither except the 30 li distance from Sungchiachuan to Tsaolinp'ing which is a portion of the latter route along the bank of the Yellow River. The rock strata exposed on the way for this portion of the trail belong to thick arkose sandstone alternative with a few red and green shales.

Southwest of Tsaolinp'ing the trail follows a deep canyon of a stream which represents a stage of vertical cutting now still active. The canyon is usually so narrow that the footpath is compelled to be established above it along the open wider valley of another older stage of erosion. The arkose sandstone usually exhibits distinct cross-bedding, while red shales gradually decrease here with dominant increase of green clayey deposits, until all the argillaceous beds become green as at about 3 li southwest of Tsaolinp'ing where the whole rock series may be distinguished as a separate one with a few layers of blackish shales. So from the lower Triassic red formation to its upper series no sharp boundary can be drawn for the color of sediments changes extremely gradually. But in the upper plant remains can occasionally be found from its few black shales. Nearly about 12 li along the stream the trail is up a loess ridge for a distance of 18 li where the sandstone and green shales are only scarcely visible in the deep gullies. Down the loess ridge to the bank of the Wutingho the young gully cutting may also be recognised though it seems much less dominant. The valley of Wutingho is much wider and partly cultivated into corn fields. During the author's visit most of the fields were drowned by floods due to the heavy rain of the upper course. From the bank of the river Wutingho southward to Chuankouchen at a distance of about 60 li the trail is very difficult as it crosses several ridges and deep valleys. The sandstone still belongs to arkose variety with thin green shales. Cross bedding is common. West of Chuankouchen the way being along a stream valley becomes much better. As younger vertical cutting is here again well developed the rock beds are extensively exposed and generally dip towards the west at an angle of about 3-4 degrees. 40 li west from Chuankouchen there is a village called Pailichiaho which is very important in geological sense, for west of this village the arkose sandstone is gradually replaced by gray or green quartz sandstone still alternative with thin green shales. Further west across a loess ridge to the city of Chingchienhsien the rock formation is only poorly exhibited and mainly covered by loess and reddish clay though younger gullies indicating active vertical erosion are still abundant. From a layer of dark gray shale intercalated in the gray sandstone outside of the city of Chingchienhsien the following plant fossils have been collected and determined by C. H. Pan.

Bernoullia sp.
Voltzia cf. *heterophylla* Brongn.
Voltzia sp.
Amentum sp.

As most of these species are new, it is pretty difficult before closer palæobotanical study to correlate with those of the other localities. Only one species is tentatively identified with *Voltzia heterophylla* of the lower Triassic of Europe. *Bernoullia* sp. is closely allied to *Bernoullia helvetica* which has been recorded from the Keuper bed of Europe. *Amentum* is also a characteristic genus of Triassic. Therefore from the generic character it is evident that the plant fossils from Chingchienhsien belong to the Triassic.

As a summary, no workable coal seams have been discovered from Tsaolinp'ing to Chingchienhsien although thin black shales with poorly preserved plant fossils are occasionally observed. Sandstone is the dominant constituent usually with distinct cross bedding. East of Pailichiaho the sandstone is mainly of arkose variety while west of it quartz sandstone is abundant. The transition from lower Triassic to the upper is generally without marked bed. Geological structure is simple with a general dip toward the west at an average inclination of 3-4°. Active vertical erosion prevails so as to cut numerous canyons and gullies giving rise locally to small water falls. So many trails can not follow the bottom of the valleys and are located on the high slopes of hills.

Chingchienhsien to Fushihhsien: The main route from Chingchienhsien to Fushihhsien is by way of Yenchuanhsien, but for the purpose of geological study the author made his journey first southwestward to Yungp'ingchen, thence northwestward to Wayaopu, and lastly southward to Fushihhsien at a total distance of 330 li. The trail between Chingchienhsien and Yungp'ingchen is about 80 li long and mainly follows the broad valley of Yungp'ingchuan though it is across a loess ridge after leaving Chingchienhsien. The rock strata are only partially exposed with gently dipping to west. At Fengchiaping 20 li east of Yungp'ingchen they constitute a small gentle dome structure with its flanks at inclinations of 3 or 4 degrees. Ten li east of Yungp'inchen there is a village called Shihyukou where the oil was already known in Yuan Dynasty i. e. over 600 years ago. The village is located at the mouth of a ravine and about 2 li east of the village there appears an oil seepage at the bottom of the stream Yungp'ingchuan. Here a well has been dug to a depth of 3 ft. and the oil emerges in small globules from the bedding planes or fissures of a gray fine sandy shale. A coal seam about 2 inches thick interbedded in the sandy shale is also impregnated with oil. The oil globules are generally gathered as thin film on the surface of the water. 8 catties are said to have been possibly collected daily from the oil film. 50 m. farther east from the well, the author discovered another seepage from which only a few globules of oil rise up through the water of the stream at intervals. The oil-bearing bed is also a fine sandy shale at about 4 ft. in thickness, but the latter or the lower horizon seems much poorer in oil than the former or the upper one. Between the two oil-bearing beds there is a layer of gray sandstone at least 1 m. thick. Besides the above two seepages, oil is also reported by the natives to have seeped out on the west of the first seepage along the stream bottom. But it is all covered by silt due to recent floods during the author's visit. About 40 m. to the west of the seepages, old coal mining pits are met with and the coal seam as reported by the natives is about 2 ft. thick and bituminous in character. A native coal mine now still in operation is located at Lichiakou 5 li west of Shihyukou. Here a sample has been made. The oil-bearing horizons are thus stratigraphically not far from the workable coal seam and just below it.

From Yungpingchen northwestward to Wayaopu, the route mainly follows the valley of a stream and only crosses a loess ridge when near Wayaopu. Generally speaking, the rock beds are not well exposed on the way partly due to their thick loess cover and partly due to the absence of recent vertical cutting. Between Kaochiatun and Naitoutsun, there are numerous abandoned coal pits, indicating some other coal seams above the seam being worked at Lichiakou. The inclination of the strata at Naitoutsun is much steeper, the dipping angle being usually at about 10° while the common angles at other places are scarcely over 4°.

There is a distinct local erosion surface between gray sandstones west of Naitoutsun as shown in fig. 1. This probably indicates that the deposition of

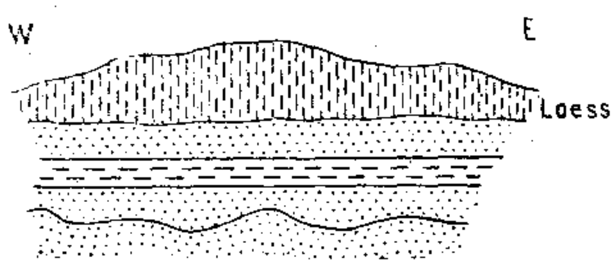


Fig. 1. An erosion surface between gray sandstones W. of Yaitoutsun, Yenchuanhsien.

the sediments is not continuous without interruption, but temporarily subject to erosion. Northwest of Lingwan there appears a fault, the rook beds being here nearly vertical without definite dipping direction as shown in fig. 2. As to the nature of the fault it is probably of the normal type and seems small in magnitude though a detailed study is still necessary for deciding this problem.

From Wayaopu to Fushihhsien the author's original plan was through Antinghsien and Ansaihsien in order to study some younger formations above the coal-bearing series, but as this route was found difficult due to political trouble he made his journey across P'anlungchen directly to Fushihhsien at a distance of 180 li. The latter route partly follows the strike of the beds. The rock exposures are generally good enough for geological purpose, though three loess ridges should be crossed. Between Tsinchuangko and P'anlungchen there crop out some thin black carbonaceous shales which are usually used by the natives for making ornamental articles. A polished section from such shales under microscope shows abundant algae-like tiny bodies. A test made in the Survey Laboratory shows the shale to contain 19.5% of oil, this is therefore an oil shale. It occurs in several layers and extends from Chilinkou, S. E.

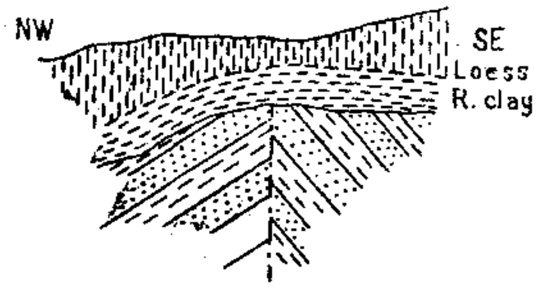


Fig. 2. Section showing a fault on the NW of Lingwan, Yenchuanhsien.

of Hengshanhsien, to P'anlungchen at a distance of 200 li. There is thus a large reserve of oil shale and its discovery is very important from economic standpoint. Old coal pits are sometimes observed on the way.

Fushihhsien to Yenchanghsien: Several seepages are reported in Fushihhsien, but during the author's visit only two are in existence. One is at Koumenshang, 25 li south of the Fushih city, where a small quantity of oil is issuing from a fine gray sandstone. The natives in the villages nearby have often used the oil for lighting lamps. Another seepage is at Paichiachuang, 20 li west of the Fushih city. The oil here comes out from the bedding plane or joints of a sandstone under a high cliff (Fig. 3 and Pl. VI, Fig. 1) and some gas bubbles also rise up here through the water at certain intervals. In fact, it is the only gas occurrence the author observed in the field. Where the oil issues a little deposit of tar is often left. This oil-bearing horizon is without doubt much higher in stratigraphic position than that at Koumenshang. Between these two seepages, oil was also formerly found at Tungchiakou, Houchiakou, and Hsiachialing, but now they are all buried by redeposited loess. Hence there are at least three oil-bearing horizons in this vicinity of Fushihhsien. The rock sediments near Fushihhsien consist of gray sandstone and green grayish shale at very gentle inclination. Beautiful ripple marks sometimes

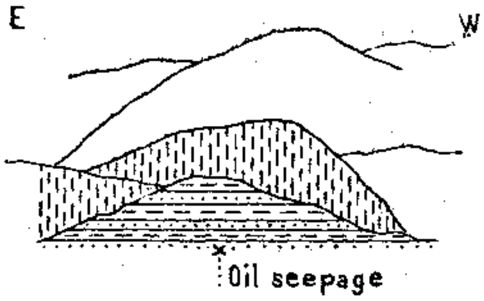


Fig. 3. Section showing the oil-bearing horizon on the SE of Paichiachuang, Fushihhsien.

appear on the sandstone west of Paichiachuang. No workable coal seams have been discovered on the west of the Fushih city, though thin layers of coal at one or two inches in thickness are not infrequently met with.

The route is mainly along the broad valley (Pl. VI, Fig. 2) of Yenshui where recent vertical cutting as commonly observed near the Yellow River is not obvious. The inclination of the rock beds is also very gentle mostly at angles of 3°-4°. 10 li east of the Fushih city is located an abandoned oil well at Chiaoerhkou (Pl. VI, Fig. 3) drilled by American Geologists. As it is just below all the oil-bearing horizons mentioned on the west of the Fushih city, little oil was struck though the depth of the well is said to have reached 3,000 ft. From Chiaoerhkou eastward to Heichiapu in a distance of 100 li there are four coal seams being worked during the author's visit. All are of bituminous character. The uppermost coal seam is being operated at Liuwangchiakou 15 li east of the Fushih city. Its thickness is reported as about 2 ft. The second seam is about 1.5 ft. thick and mined at Kaimao (Pl. VI, Fig. 4) 30 li east of the city, while the third one is about 2 ft. in thickness and located at Paichiaya 50 li east of the city. The third seam being said to be the best in quality, the last locality is the most productive place along the Yenshui valley. During the author's visit to Paichiaya from the Fushih city he met a great number of mules and donkeys on the way for transporting coal to the city. The relation of the third and fourth seams is not clear though the fourth seems to be a separate seam much lower in stratigraphic position than the third and now being worked at Shihmakou, about 60 li on the southwest of Yenchanghsien. At Yailichiaping 5 li west of Kaimao the following species of plant fossils have been collected as derminated by Mr. Pan.

Cladophlebis (todites) williamsoni Brong. froma whitbiensis
Lower Oolitic-Rhætic.

cf *Baiera taeniata* F. Braun. Lower Liassic-Rhætic
Baiera sp.
Sagenopteris nilssoniana Brongn. sp. Liassic-Rhætic
Pityophyllum nordenskioldi (Heer) Jurassic.

It is evident that these species belong to the Liassic or Liassic-Rhætic.

East of Paichiaya there is a tiny village Yangchiapien about 90 li on the west of Yenchanghsien, which is very in portant from geological standpoint. On the west of the village the sediments are composed of black and greenish shales, coal seams and gray sandstones, while on the east they consist mainly of gray sandstone with thin greenish shales and without workable coals. The former are distinctly of Jurassic age with thick gray basal sandstone exposed between Yangchiapien and Yaotientzu. The latter were formerly assigned by the author as a portion of the Lower Jurassic coal series, their color being dominantly gray or greenish with some thin coals and thus easily classified into the coal series. This mistake was also followed by American oil geologists in their recent publications. But now they seems to be upper or middle Triassic in age, according to the new collections of plant fossils at Chingchienhsien and Yenchanghsien.

From Heichiapu to Yenchanghsien two routes are possible; one follows the Yenshui valley and the other is across a loess ridge. The author travelled the latter, and after reaching the top of the ridge he was surprised by the wonderful feature of a loess plateau on which have been established numerous corn fields and villages. One would think that he had stood on a plain if he forgot his climbing up a partially dissected plateau. The gray sandstones commonly exhibit dominant cross-bedding.

Yenchanghsien is the oil-producing centre in north-Shensi and numerous oil seepages have been reported near the Yenchang city. In fact, during the author's visit there are only five seepages available which seem to represent four oil-bearing horizons. The first seepage which indicates the uppermost oil-horizon is situated at Chiaochiashihko (Fig. 4 and Pl. VII, fig. 1) 15 li northwest of the Yenchang city. Here it is exposed in a

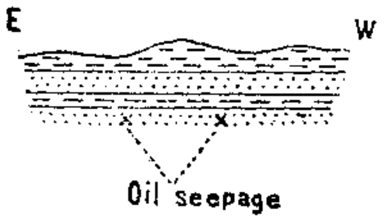
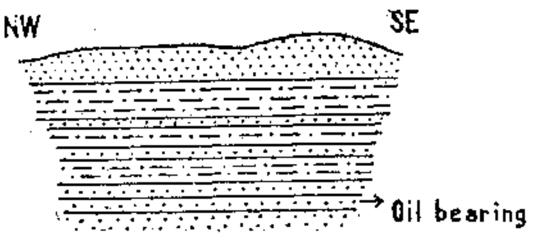


Fig. 4. Section showing the oil-bearing horizon on the E. of Chiaochiashihko, Yench'ang-hsien.

narrow gorge due to recent vertical cutting. The oil emerges from two spots 10 ft. apart, leaving a black deposits of tar on the rock surface. The oil horizon is a thin-bedded grav sandstone about 3 or 4 feet thick. But as it soon becomes sandy shale along its strike, the oil can not be found again elsewhere. Near the west gate of the Yenchang city there is an ages known seepage on which the Yenchang well No. 1 is situated. During the visit, however, only a little stain of oil on the loess surface appears. This oil bed are obviously much lower in stratigraphic position than the Chiaochiashihko horizon. The third seepage is situated at Yenwukou (Pl. VII, Fig. 2) 10 li northeast of the Yenchang city. Here the oil comes out with a water spring as globules which soon make a thin black film on the water surface. A sample has been taken for analysis. The oil is generally issuing from the bedding fissures of a fine-grained thin-bedded sandstone. Nearly 100 metres south of the seepage a few globules of oil also rise up through the water at intervals in the bottom of the valley, while 6 li north of the seepage there is located an abandoned well formerly drilled by American geologists. Two hundred catties of oil were produced daily according to the report of the natives, but now the well is filled with loess and only ruined walls (Pl. VII, Fig. 3 and Pl. VIII, Fig. 1) of the office building are left nearby. From Yenwukou southeastward down the valley to Huchiachuan at its junction with the Yenshui, a fourth seepage consists of tar thickly deposited on a bed of fine-grained thin-bedded sandstone (Fig. 5 and Pl. VIII, Fig. 2) about 0.8 m thick. Whether this is a



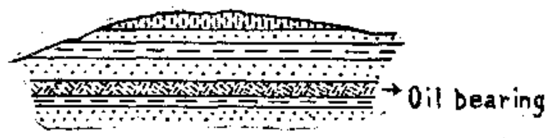


Fig. 5. Section showing the oil-bearing horizon (fine grained sandstone) on the NW of Huchiachuan, Yench'anghsien.

Fig. 6. Section showing the oil-bearing horizon on the SE. of Liaotzeyuan, Yench'anghsien.

separate horizon from that mentioned at Yenwukou is not clear. Ten li eastward down the Yenshui valley from Huchiachuan there occurs the fifth seepage in a deep ravine one li south of the village Liaotzuyuan (Fig. 6 and Pl. VIII, fig. 3). Here only a little oil stain and tar deposit appear on a cross-bedded gray sandstone at about four metres in thickness. This probably represents the fourth or lowest oil-bearing horizon.

Though the rock strata in the neighborhood of Yenchang are mostly regularly inclined, a gentle anticlined structure may be outlined by a careful examination. Its axis trends nearly east-west with its north limb dipping north at only one or two degrees and its south limb also dipping as much, while the five seepages mentioned are all distributed along its axial zone. At Huailinp'ing six li west of the Yenchang city the following fossils have been found from a layer of gray sandy shale intercalated in the gray sandstone:

Schizoneura paradoxa Schimper Buntsandstein-Keuper.
Equisetites sp.
Asterocarpus virginiensis var. *obtusilobus* Fontaine, Rhætic.
Dichopteris sp.
Amentum sp.
Aethophyllum sp.

As most of these species are new, they are difficult in correlation of geological age, but according to the generic character there is no doubt that they belong to the Triassic.

Yenchanghsien to Yunghohsien and Shihkouchen in Shansi. The journey was so rapidly made that only a rough reconnaissance survey to the geology was possible. Generally speaking, between Yenchanghsien and Chiaokouchen the sediments are composed chiefly of gray quartz sandstone commonly cross-bedded and of thin greenish shales, while east of Chiaokouchen through Yenshuikuan across the Yellow River to a place 30 li west of Yunghohsien they consist dominantly of reddish arkose sandstone alternating with thin green shales. All these strata are included in the upper or middle Triassic. From Yunghohsien northeast to Shihkouchen arkose and red quartz sandstones with red shales prevail and these are provisionally assigned to Lower Triassic in age. East of Shihkouchen comes the Cambro-Ordovician limestone which often forms high rocky hills surrounding the above Mesozoic sediments. The contact of the limestone formation with Mesozoic red beds is caused by a big normal fault with the Permo-Carboniferous coal series cut away.

OIL HORIZONS.

North Shensi as a whole is constituted mostly by Mesozoic sediments except its southern margin near the Weiho basin and further these are thickly covered by Cenozoic deposits. The inclination of the Mesozoic strata is generally from 1° or 2° to 3° or 4° in a dominant direction towards the west. Notable major folding is rare though not entirely absent. Minor faults of small throw are, however, not infrequently met with and these are the only localities where the steep dipping or vertical beds are visible.

The collection of the plant fossils at Yenchang and Chingchien is very important, as the lower part of what was called "Lower Jurassic coal series" is now proved to be Triassic. As a summary, the stratigraphic succession of the Mesozoic sediments may be stated again as below:—

1. *Lower Triassic red beds:* This conformably overlying the Permo-Carboniferous coal series is composed of red shale alternative with thin red sandstone in its lower portion, of red sandstone interbedded with thin red greenish shales in its upper. It is at total thickness of about 600 m to 800 m as estimated from its exposure. Only in its lower portion were discovered plant fossils[1] for determining its geological age.

2. *Upper or Middle Triassic gray sandstone and green shale:* This was formerly included in the Lower Jurassic coal series[2] and conformably rests on the Lower Triassic red beds. Its lower part consists dominantly of arkose sandstone while its upper one mainly of gray quartz sandstone. Cross-bedding is common. Green or blackish shales are subordinate, but they sometimes contain well preserved plant fossils. The thickness of the whole series is estimated at about 1000 m by supposing the average angle of inclination at 1°. Of course, this is by no means accurate for a great number of local disturbances is not counted. The special feature of the sediments is abundance of local disconformities and of notably lateral change of lithological characters. The thickness of each individual bed is also notably variable. All these probably indicate that the sediments under consideration belong to a delta deposit.

3. *Lower and Middle Jurassic coal series:* It is built up of gray or white sandstone, green or gray to black shales and coal seams at a total thickness of about 800 m as estimated by the same method as for the preceding formation. Four coal seams are workable but the thickness of the individual seam is scarcely over three feet except in Chungar, Ordes, and in Chenchiangpu and Yunghsingpu between Fuku and Shenmu where a 18-foot thick coal seam exists. A number of plant fossils having been collected at Kaimao 30 li east

1. C. C. Wang: Stratigraphy of Pao Teh Chou, Northwest Shansi, Bull. Geol. Surv. China No. 3, 1921.
2. C. C. Wang: Stratigraphy of North Shensi Bull. Geol. Soc. Vol. 4, No. 1, 1925.

of the Fushih city, belonging to the Liassic or Liassic-Rhætic. At Hsialanniwan, northeast of Hengshanhsien, in the upper part of this series a Cycad, **Dioonites brongniarti Seward,** was obtained by the author in 1923. This species belongs to the Middle Jurassic. So it is probable that the upper part of this series, which is also composed of gray sandstones and shales but contains no workable coal seams, may belong to the Middle Jurassic.

As to the oil horizons three groups can be distinguished, two of which are included in the upper or middle Triassic gray sandstone and shales, and one is in the lower Jurassic coal series. The lower group of oil horizons being exposed near the Yenchang city is called the Yenchang group consisting of four oil-bearing horizons. On its third horizon in ascending order the present Yenchang oil well is being worked. The second group is named the Yungping oil-bearing group from the town of Yungpingchen, which is composed of two oil horizons, while the third is assigned as the Fushih group derived from the Fushih city which is built up by three oil horizons. What group is the richest in oil is difficult to answer, for little prospecting has been made in the second and third groups. It is, however, possible that the first and second groups may be the richer according to the existing seepages, or in other words the oil-bearing horizons in the upper or middle Triassic gray sandstone and shales seem to be the richer.

Since the oil generally emerges from the bedding planes or fissures of the oil-bearing beds which are mostly gray sandstone and little oil is contained in the pores of the sandstone, it is probable that the oil in the present oil-bearing beds was migrated from some other horizons. In what horizons was formed the oil is not easy to say and rather theoritical. Two horizons are, however, suggestive for oil derivation in the area visited, though they can not yet be well proved. On the southwest of the Yenchang city at about 60 li from the bank of the Yellow River Mr. C. Y. Hsieh has discovered a bivalve bearing black shale about 6 inches thick near the bottom of the upper or middle Triassic gray sandstone and green shales. Abundant fossil-fish scales are also preserved in this shale which was taken by Mr. Hsieh as the source of the oil. The Yenchang and Yungping groups of oil horizons which are stratigraphically directly above the bivalve fossilliferous shale may possibly have some genetic relation with such shale. Above the third coal seam mentioned in the Lower Jurassic coal series there occur some thin layers of oil shale. Under micro-scope a polished section shows numerous minute bodies much like algæ of boghead coal. These layers of oil shale may be taken as another derivative horizon of oil especially for the Fushih group above them.

YENCHANG EXISTING OIL WELLS.

Though the oil in north Shensi has been known since very ancient times, only a little quantity collected from the seepages was then used for medicine or lighting lamps and no drilling was attempted for large engagement. The first Yenchang well No. 1 (pl. VIII, Fig. 4) was drilled in 1907 near the west gate of the Yenchang city. It has a depth of about 226 ft. The production of oil was about 200-300 catties per day during 1907-15; increased to about 1700-2000 catties daily in 1916-17, and then diminished to the first amount again up to the present. The life of the well has elapsed 26 years.

Yenchang well No. 2 was about 320 ft. deep and could yield 200 catties per day as reported by the Yenchang oil refinery, but now it is abandoned. Yenchang well No. 3 only struck trace of oil through a depth of 549 ft. In 1929 the present manager Mr. Pao of the refinery drilled a new well 300 m distant from the Yenchang well No. 1 on its northwest at a depth of 520 ft. The maximum daily oil production of the new well once reached 15,000 catties as recorded by the refinery. But at present it can only produce 100 catties per day.

There are some other abandoned wells drilled by American oil geologists, of which one is at Yenwukou 10 li northeast of the Yenchang city and the other at Chiaoerhkou 15 li east of the Fushih city. The former is said to have originally yielded 200 catties daily while the latter only struck trace of oil.

RECOMMENDATION FOR SOME WELL DRILLINGS.

After the drilling of Yenchang wells in 1907-10, large reserves of oil were generally believed to exist in north Shensi. The Government thus paid special attention to develop the oil field. But it was soon considered as a poor oil field since the prospecting of American oil geologists in this region. In the author's opinion as a result of his visit to this district, further prospecting is still deemed and necessary in view of the extensive need of oil and scarcity of oil fields in this country. The common method for locating wells is according to the geological structure. The inclination of the rock strata in the region under study is, however, so gentle that any notable structure is hardly to be detected except that the oil seepages at Yenchang seem situated on the crest of a very gentle anticline. The use of geological structures for putting wells is thus of little value in the visited district. The present Yenchang wells have been their position generally located upon the oil seepages. With the seepages as aid to locate wells, a great number of other sites may be fixed besides the proximity to the Yenchang wells now being in operation. The most favorable localities are (1) at Leichiatan outside the east gate of the Yenchang city (2) at Shihyukou 10 li east of Yungpingchen. In the former are recommended four drillings and in the latter are six. The detailed distribution of such recommended drillings is shown in the attached maps. If they are successful, other drillings such as at Yenwukou, Chiaochiashihko, Kuomenshang, and Paichachuang etc. may be continued.

OIL SHALE.

Oil shale was not known neither to the natives nor to the American oil geologists until the author's visit. A 20 gram sample from Chilinkou, S. E. of Hengshanhsien gives the following data on distillation in the Fuel Laboratory of the Geological Survey:

Oil vapor at 180°C. Oil drops at 311°C.

Gas at 383°C. Heavier oil at 418°C (brown color)

Percentage of oil in the sample — 19.5%

Specific gravity of oil—0.8730.

Similar shale was found at Panlungcheng between Anting and Fushih districts (Plate I). It is probable that these outcrops of Chilinkou and Panlungcheng are from the same horizon which extends further north and southward. The distance between the two mentioned outcrops is about 100 km, between which at least the continuity is the most probable.

At Chilinkou, the oil shale is about 4 feet in total thickness. But it is separated into several thin layers by thin sandstone. The thickness of each individual layer varies from a few inches to one foot. The total thickness of the oil shale is a little greater at Panlungcheng, about 5-6 feet, also consisting of several separated layers of less than one foot.

In view of the scanty data yet available, it is premature to predict in any definite way on the economic prospect of the oil shale formation. However in order to have some idea of the order of magnitude a tentative estimate may be roughly made.

The minimum extention of the oil outcrop in N-S direction between Chilinkou and Panlungcheng is about 100 km. Assuming a westward dip of about 10°, there is a workable width of at least 2,400 m to a depth of 300 m. The thickness or rather the thinness of the shale is the main objection to its workability. Accepting the rather minimum figure of thickness say 1 m, and assuming the specific gravity of the shale to be 2.5, there would be a reserve of this shale of 240,000,000 tons. Instead of 53 gallons per ton as given by the analysis of the Chilingkou sample, let us assume only half of it say 26 gallons per ton, the reserve of oil would amount to 15,600,000,000 gallons or 371,000,000 barrels.

Plate I

陝北油田地質圖
GEOLOGICAL MAP OF THE OIL FIELD OF NORTH SHENSI

縮尺二百萬分之一

Scale 1:2000,000

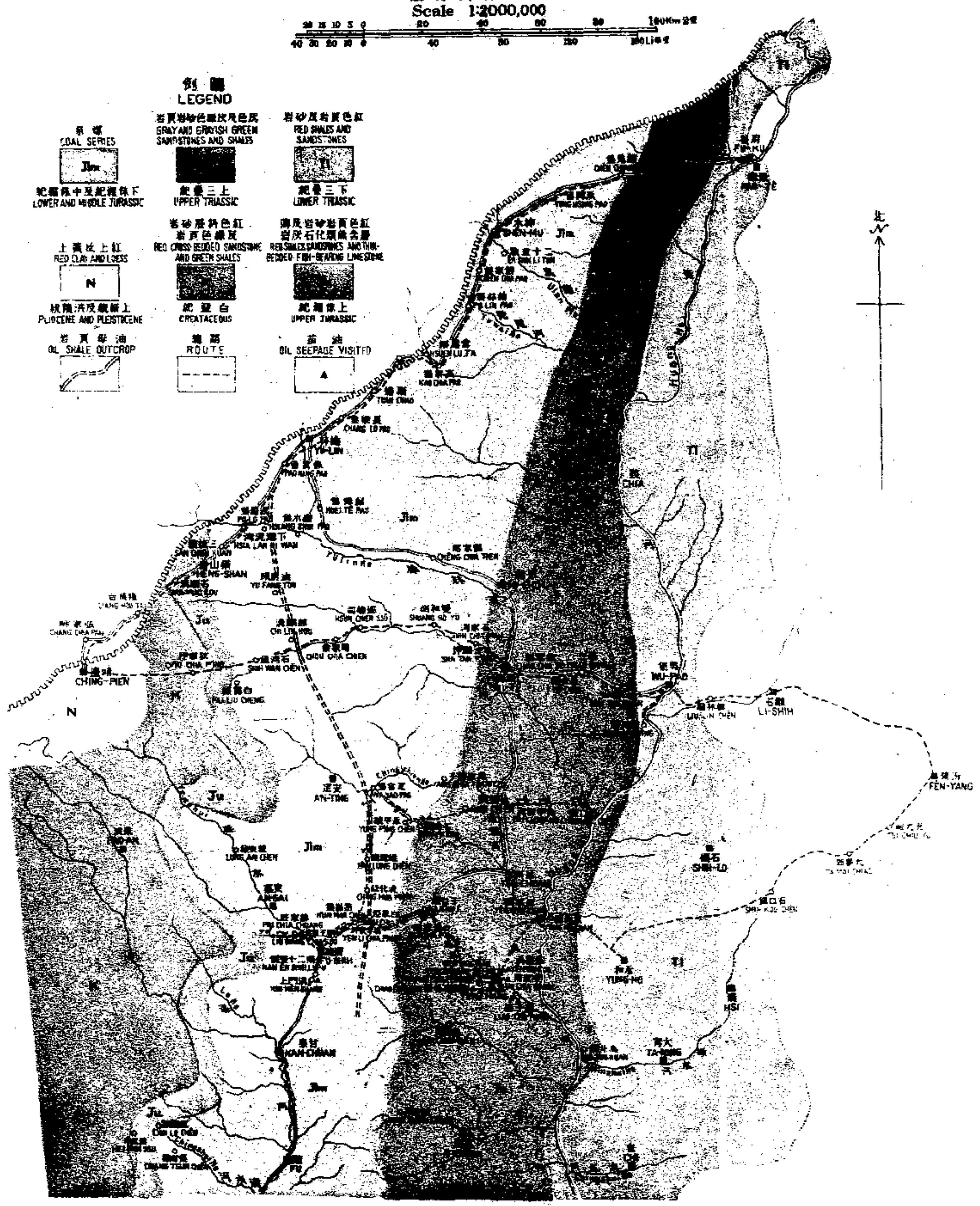


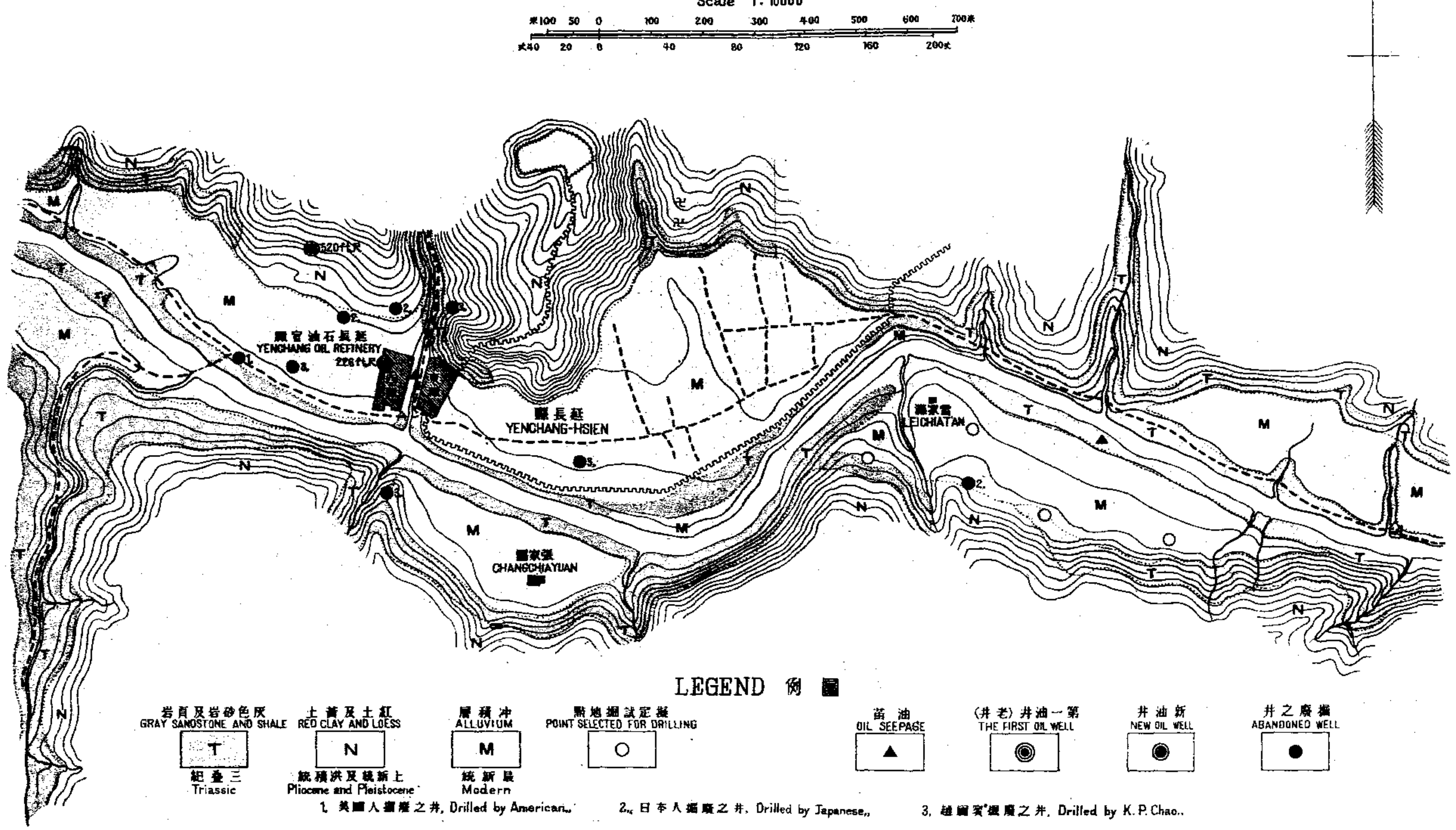
Plate II

延長油田略圖

SKETCH MAP OF YENCHANG OIL FIELD

縮尺一萬分之一

Scale 1:10000



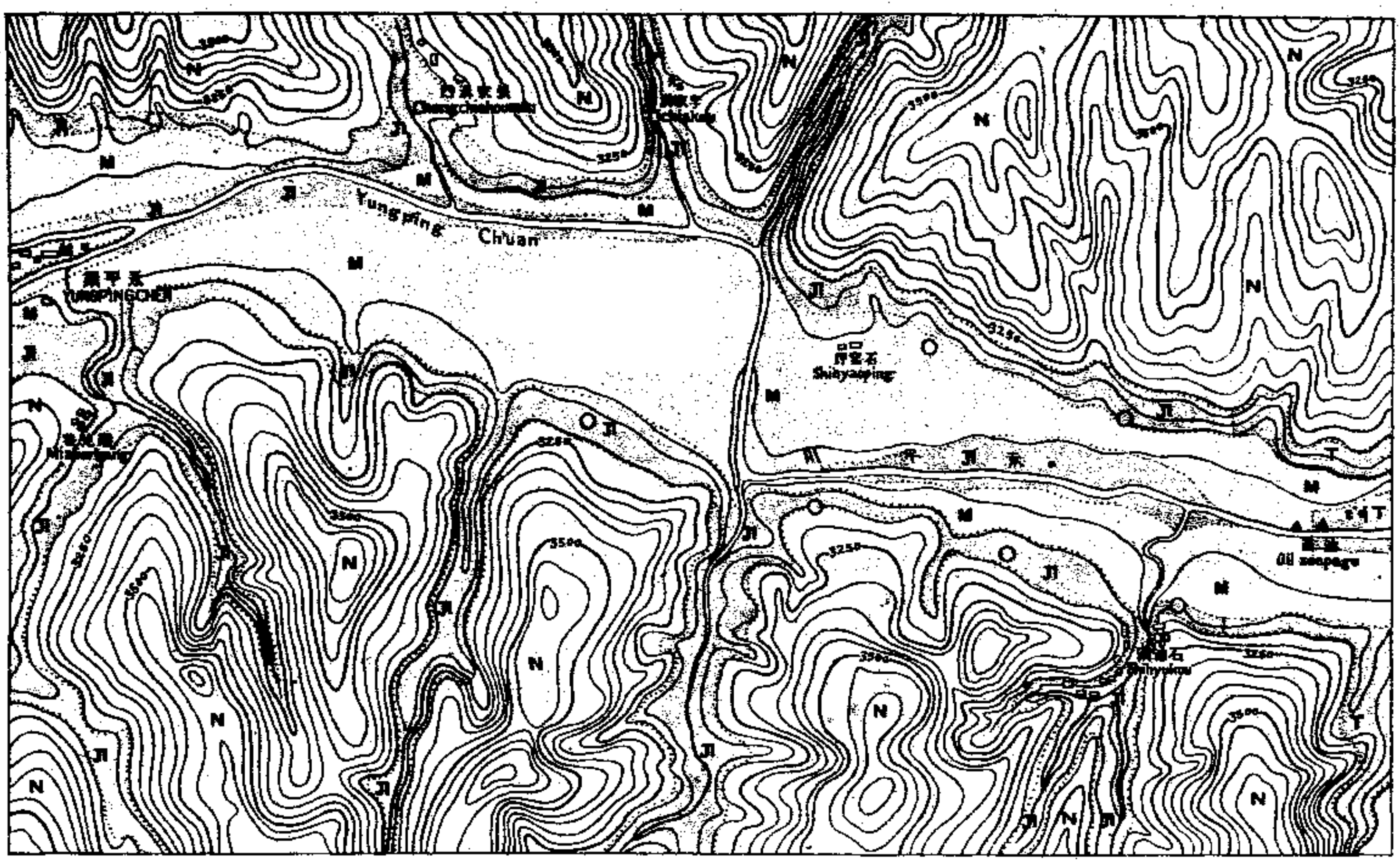
延川永平鎮油田地質圖
GEOLOGICAL MAP OF THE OIL FIELD OF YUNGP'INGCHÊN, YENCHÜAN

縮尺三萬四千分之一

SCALE 1:24000

等高線距五十英尺

CONTOUR INTERVAL 50 FEET



LEGEND 圖例

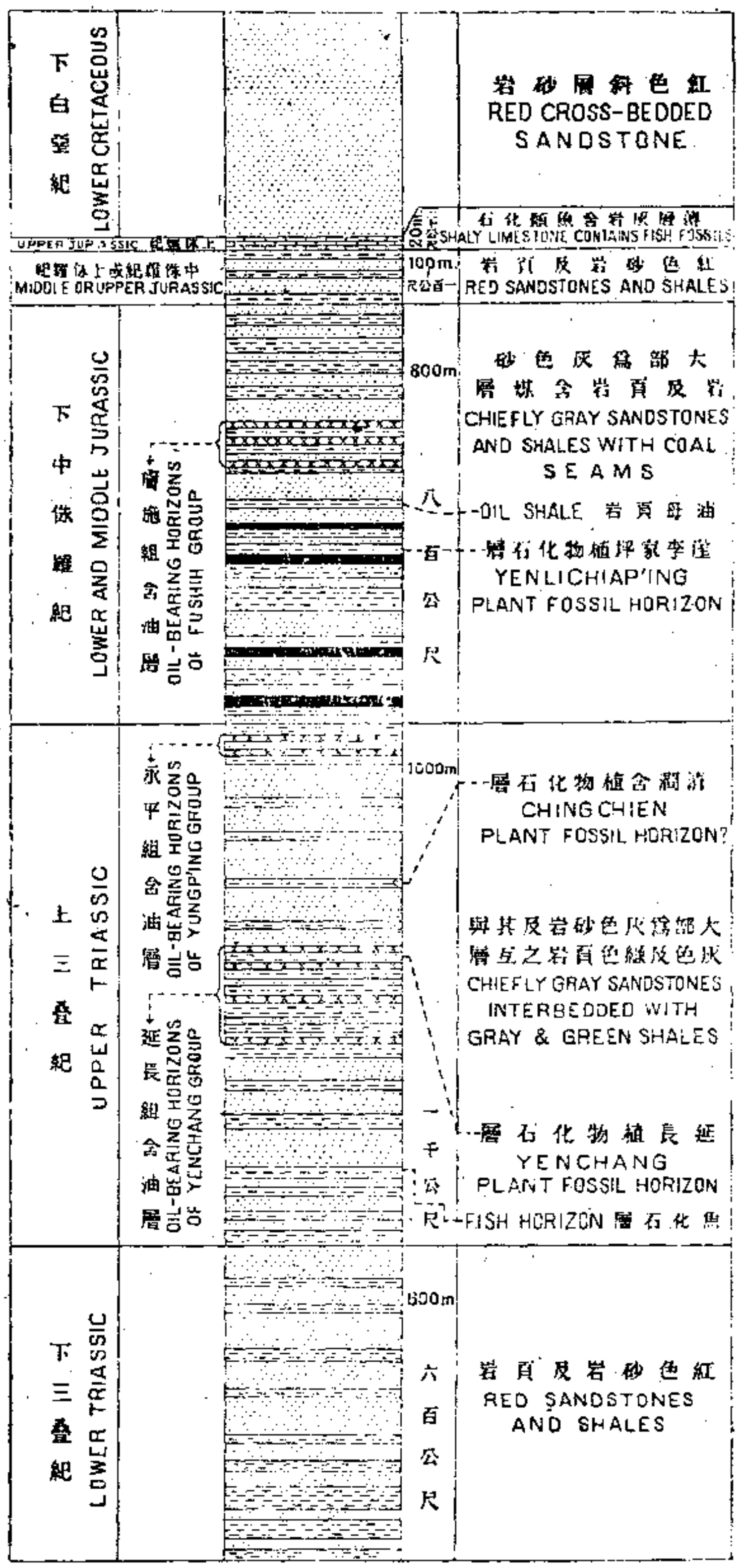
灰色砂岩及頁岩 GRAY SANDSTONE AND SHALE	煤系 COAL SERIES	紅土及黃土 RED CLAY AND LOESS	沖積層 ALLUVIUM	
T	Jl	N	M	○
三疊紀 Triassic	下侏羅紀 Lower Jurassic	上新統及洪積統 Pliocene and Pleistocene	最新統 Modern	擬定試掘地點 Point selected for drilling

Plate IV

陝北地層剖面圖
A GENERLIZED SECTION ACROSS NORTH SHENSI

平距縮尺二十五萬分之一
HORIZONTAL SCALE 1:250,000

Plate V


下白堊紀
LOWER CRETACEOUS
紅色斜層砂岩
RED CROSS-BEDDED SANDSTONE
UPPER JURASSIC
薄層灰岩含魚類化石
SHALY LIMESTONE CONTAINS FISH FOSSILS
中侏羅紀或上侏羅紀
MIDDLE OR UPPER JURASSIC
100m.
紅色砂岩及頁岩
RED SANDSTONES AND SHALES
下中侏羅紀
LOWER AND MIDDLE JURASSIC
富施組含油層
OIL-BEARING HORIZONS OF FUSHIH GROUP
800m.
大部為灰色砂岩及頁岩含煤層
CHIEFLY GRAY SANDSTONES AND SHALES WITH COAL SEAMS
八百公尺
OIL SHALE 油母頁岩
崖李家坪植物化石層
YENLICHIAP'ING PLANT FOSSIL HORIZON
上三疊紀
UPPER TRIASSIC
永平組含油層
OIL-BEARING HORIZONS OF YUNGP'ING GROUP
延長組含油層
OIL-BEARING HORIZONS OF YENCHANG GROUP
1000m
清澗含植物化石層
CHINGCHIEN PLANT FOSSIL HORIZON?
大部為灰色砂岩及其與灰色及綠色頁岩之互層
CHIEFLY GRAY SANDSTONES INTERBEDDED WITH GRAY & GREEN SHALES
一千公尺
延長植物化石層
YENCHANG PLANT FOSSIL HORIZON
FISH HORIZON 魚化石層
下三疊紀
LOWER TRIASSIC
600m
六百公尺
紅色砂岩及頁岩
RED SANDSTONES AND SHALES

Explanation of Plate VI

第 六 版

Plate VI.

第一圖. 膚施縣排家莊東石㠌壁下之油苗.

Fig. 1. An oil seepage under the rock cliff on the east of Paichiachuang, Fushih Hsien.

第二圖. 自膚施縣拐茆鎮西望延水川谷之景.

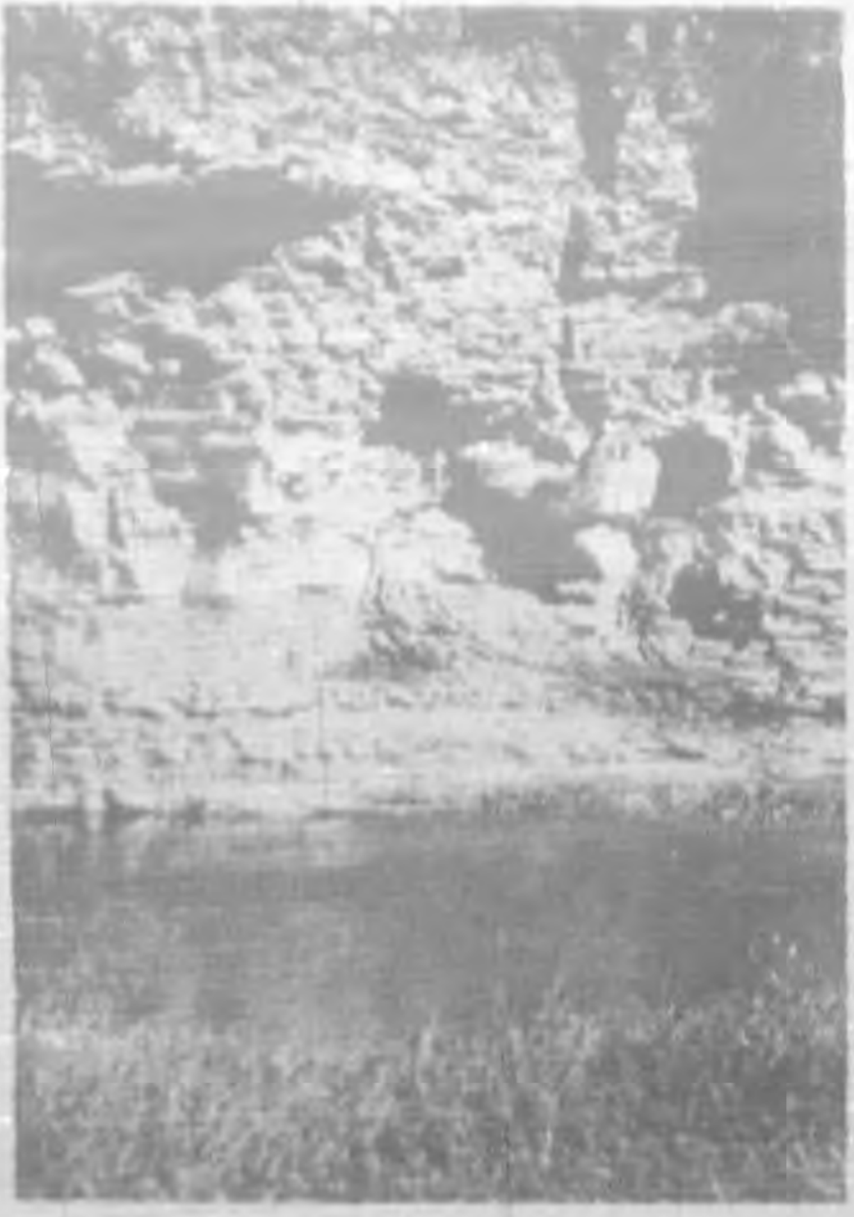
Fig. 2. View of the Yenshui valley flat looking west from Kaimôchên, Fushih Hsien.

第三圖. 膚施縣喬尔溝美孚採礦油井上之砂岩層.

Fig. 3. The sandstone bed above the abandoned prospecting oil well, Chiaoerhkou, Fushih Hsien.

第四圖. 膚施縣拐茆鎮附近土法採煤之景.

Fig. 4. View of the native coal pit near Kaimôchên, Fushih Hsien.



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Explanation of Plate VII

第 七 版

Plate VII.

第一圖. 延長縣城西喬家石科含油層之露頭.

Fig. 1. Outcrop of the oil-bearing horizon at Chiaochiashihko, west of Yench'ang Hsien.

第二圖. 延長縣烟霧溝之石油苗.

Fig. 2. An oil seepage at Yenwukou, Yench'ang Hsien.

第三圖. 延長縣王家河美孚採礦廢井附近之房屋.

Fig. 3. Ruined buildings near the abandoned prospecting oil well at Wangchiaho, Yench'ang Hsien.

第七版 Plate VII.

Explanation of Plate VIII

第 八 版

Plate VIII.

第一圖 延長縣王家河附近美孚探鑛技師遺留之鐵管

Fig. 1. The iron pipes abandoned by the American oil geologists near Wangchiaho, Yench'ang Hsien.

第二圖 延長縣呼家川西北含油層之露頭

Fig. 2. Outcrop of the oil-bearing horizon on the N. W. of Huchia-chüang, Yench'ang Hsien.

第三圖 延川縣城東二十五里蓼子原附近十字形含油砂岩層

Fig. 3. The cross-bedded oil-bearing sandstone near Liaotzeyüan about 25 li east of Yench'ang Hsien.

第四圖 延長石油官廠老井橹台及蒸汽鍋爐房

Fig. 4. The steam boiler room of the Yench'ang well No. 1.

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