

實業部地質調查所

國立北平研究院地質學研究所

# 地質彙報

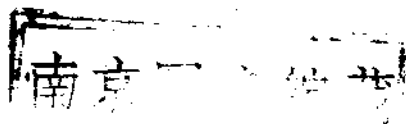
第二十三號

民國二十二年十二月

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華煤中硫質種類之分析·····	楊珠瀚
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綏遠白雲鄂博鐵礦報告·····	丁道衡

北平西馬路九號地質調查所圖書發行



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# 江西玉山廣豐二縣地質礦產

高平

## 引言

民國二十二年春，奉所長命赴浙贛邊境調查煤田地質。浙江西南部，迭經本所劉寄辰趙亞會王恆升李春昱諸君，兩廣地質調查所樂森璋蔣溶二君，及浙省礦產調查所諸君調查，並皆有報告發表，故此調查，側重於贛東玉山廣豐兩縣，該處雖前經東京地學協會日本學者一度考察，並繪有地質圖發表，但對於地層系統及構造均未察定，且多誤解。贛東地形圖，最為簡陋，所得者，僅二十萬分之一軍用圖，及各縣自繪之平面圖，故側製地質圖，困難萬分，此次除廣豐東北鄉煤田，自行測製二萬五千分之一（縮印為五萬分之一）地形地質圖（見第一版）凡一百三十方公里外，此外僅就上述簡陋圖上，稍加改正，製成十萬分之一地質圖（縮印為二十萬分之一見第二版）凡一千二百方公里。

此次調查，計自二十二年三月十八日由北平出發，二十一日抵杭州，二十七日由杭江鐵路至蘭谿，次日抵衢州，即赴下石埠後溪街考察煤田分佈，四月四日至江山城，研究附近古生代地層之層次及分佈，並採集化石，四月十一日自江山城南行，至禮賢鎮，調查該地煤礦，十七日抵江西廣豐縣城，十九日赴排門一帶測製煤田地形地質圖，計費時十四日，于五月四日回廣豐城，次日赴北鄉吳村一帶考察煤田地質，五月八日抵大南橋，詳勘奧陶紀地層之分佈及層次，廣搜化石，並赴上饒縣六十六都王坑煤田勘察，十三日抵玉山縣城，十七日至八都調查玉山東南鄉煤田地質，二十三日仍回玉山城，調查東北鄉及北鄉地質，月底由玉山城經浙省之常山衢州轉杭返平。是役也，野外調查日期，共閱六十餘日，本區（玉山廣豐二縣）內除阻於雨及路途或雜事所耽誤者外，實地工作時間計為三十二日。

贛東久為共匪所蹂躪，現雖略告平靜，而玉山西北鄉及廣豐南鄉均尚為紅軍盤踞中，調查區域，亦有小股土匪不時出擾，幸賴熊天一主席電令泰王二縣長隨地設法保護，得安然從容調查，特誌之以表謝忱。

## 地形

本區地當信江上流，東以仙霞嶺脈與浙江接壤，東南望武彝山脈而與福建接壤，北屏懷玉山脈，山嶺叢雜，僅玉山廣豐縣城附近，有大片平原焉。

本區四周大山，率多成自武彝系地層，傾斜甚緩，且與其下岩層拗曲不相一致，故古生代地層之走向，雖極為規則，而山脈方向，除中部古生代地層所成諸山脊大致方向有一定規則外，率縱橫靡定，如仙霞嶺山脈為南北向，武夷山脈作東北西南向，懷玉山脈則變成東西向。

河流，以仙霞嶺為分水界，仙霞嶺以西，河流均向西流，玉山境內，下鎮溪，鎮川，發源於仙霞嶺，金沙溪，瑯溪，發源於懷玉山脈，向西合流，是為冰溪，至上饒縣而入於信江。廣豐東南鄉，諸小河流，發源於仙霞嶺及武彝山脈，匯為杉溪，西流至上饒而入於信江。在本區內，冰溪，杉溪四季可暢行舟楫，金沙溪，瑯溪下流亦可通小舟外，餘則不過小溪淺流，夏季水流湍急，冬季則多乾涸，無舟楫之利也。

## 地文

本區地文，與浙西所見者相類似，前劉超二君謂：「浙西高山，遙視之略成水平線，古代侵蝕平原之遺跡，隱約可辨，以地文期言，此侵蝕平原，或與鄂西期相當。」此次調查所見，顯可分為三期：

- (一) 仙霞期——白堊紀以後之剝蝕平原。
- (二) 贛東期——寬廣河谷及盆地之造成，第三紀赭色砂礫岩之停積。
- (三) 衢江期——現代河流所深切之幼年地形。

(一) 仙霞期——仙霞期為區內所見最古之地形，其高度約在一千公尺以上，組成浙贛閩交界一帶最高之山頂，因剝蝕關係，本期地形之得保存者殊少，此次觀察所及，江山縣西南境之仙霞嶺脈各山，玉山北境懷玉山脈各山，及廣豐東南武彝山脈各山之

頂，遙望之均宛若於同一水平線上，考其高度，亦均在千公尺左右，似爲同一侵蝕平原之遺跡。又據浙省陸地測量局所測地形圖觀察，（浙省所測地形圖，精密準確爲各省冠。）浙江南部，亦多此類高山。考諸地質，此類高山，率多成自白堊紀之武彝層，以理揣測，白堊紀火山活動告終之季，贛東及浙江南部幾盡爲所淹，迨後剝蝕繼之，而成一侵蝕平原，故仙霞期之時代可斷定爲白堊紀之後，第三紀赭色岩層停積以前也。或與湖北之鄂西期相當。

（二）贛東期——仙霞期剝蝕平原造成之後，繼以造山作用，使大陸逐漸上昇，當其上昇之時，剝蝕隨之，於是一方使山之高度，日增靡已，成今日高出海拔千公尺諸高山。一方則剝蝕日劇，寬廣河谷及盆地之造成，衢江赭色岩系礫岩砂岩頁岩之造成，與夫古生代地層之重行出露，卽其侵蝕之結果也，其地形成中年狀態，是爲贛東期。玉山廣豐縣城附近之大片平原，卽爲盆地所造成，至如浙省衢江流域兩岸寬廣河谷之遺跡，更爲顯著。贛東期之時代，自當更後於白堊紀，而隨第三紀赭色岩系停積之告終而完成。

（三）衢江期——本期地形，皆切於贛東期之上，組成狹谷深溝，凡現代河流切成幼年時代之溝谷，無不屬之，至今猶繼續進行也。是爲衢江期。本區冰溪，杉溪及其支流所經，及浙省衢江所切於第三紀赭色岩中之幼年期深狹河床，均甚明顯。

### 地層

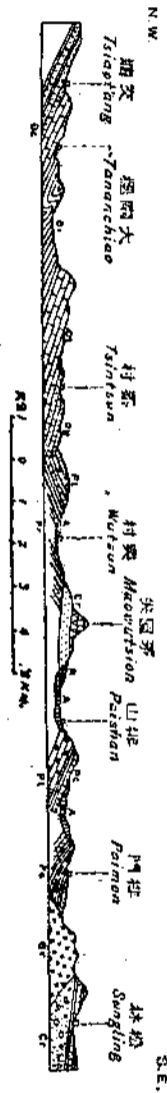
此次調查區域內地層，與浙省西南部大致均可比較，故地層名詞除少數因特殊情形外，均力求引用舊名：如下奧陶紀地層，劉趙二君總其名爲印渚埠系，但在贛東特別發達，厚度既大，露頭又往往縱橫數十里，而據岩石性質及化石層次，顯可分爲三層，故爲明瞭構造上關係，不得不詳分而另易新名詞（見第三版），茲將各層自下而上，分列如下：

- （一）交塘系·····
  - （二）玉山頁岩·····
  - （三）大南嶺石灰岩·····
- 奧陶紀



- (四) 秦村系..... 奧陶紀
- (五) 飛來峯石灰岩..... 二疊紀
- (六) 禮賢煤系..... 二疊紀
- (七) 薄層石灰岩..... 三疊紀
- (八) 武彝層..... 白堊紀
- (九) 衢江赭色岩系..... 第三紀
- (十) 沖積層..... 近代

圖面剖 C C 間豐廣山玉 圖一第



本區地層，下奧陶紀及二疊紀地層最為發達，惟其他地層，遠不如浙省西南部發達；蓋全區為一北北東—南南西方向之大斷層所隔，斷層以東為二疊紀及較新地層，斷層以西，則為奧陶紀地層，志留紀及泥盆紀地層，均付缺如；三疊紀之薄層石灰岩，浙西閩北，均未發現，而在廣豐縣之杉溪見之；可知三疊紀時代之海水，亦曾前進至此，不過其停積物為白堊紀以前之大侵蝕時代所剝削而殘留無多，且一部尚為武彝層所掩蓋也。茲分述如後：

(一) 交塘系——為調查區域內最古地層，此次首見於廣豐之交塘，故名。岩石以細砂岩為主，下部為深黑色板狀頁岩，富含土瀝青質，每層厚三分至七分，可用以燒石灰，俗名石煤，燃燒時發氣二硫氣甚大，燒後成紅棕色細砂岩，與其上之細砂岩相似，可知二者為相同之停積物，不過因生物作用而加以瀝青質耳。細砂岩之上為一層灰白色之石灰岩，惟層理間常夾紫色及灰

黑色之泥質薄層，石灰岩有時成結核狀嵌於泥質層中，方解石脈，縱橫四列，巨大完善之結晶甚多，其層次及厚度如下：

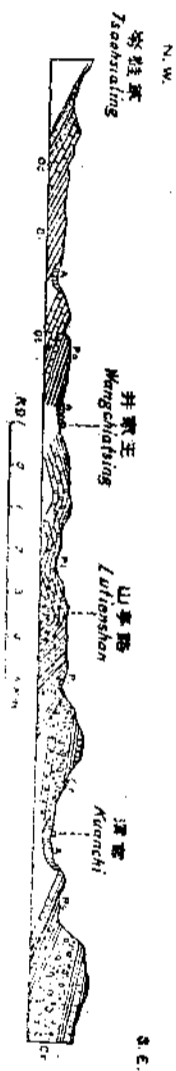
黑色板狀頁岩夾石煤——一百公尺

黃棕色薄層細砂岩——一百七十五公尺

石灰岩夾泥質層——八十公尺

自廣豐大南橋西南新塘東北行經交塘入玉山境之草鞋岑而至玉山縣城南之武安山，再由玉山城東北之大山底東北行經屏風關而直至常山境內，為本系岩層最發達之區，地層大致均向東南傾斜，惟草鞋岑武安山一帶，地層更有分向西北傾斜之勢，成一背

圖二第 D D 剖面 廣山玉 圖二第



斜層構造；此外如玉山西北鄉橫街附近，亦有斷露出露之本系岩層。調查區域內，本系岩層所經，灰窰林立，堪稱盛業，蓋原料均取自本層之石灰岩及石煤，故成本輕廉而取用不竭。

(二)玉山頁岩——本層以玉山縣城東北及廣豐大南橋(第二版及第一圖)附近最為發育，整合覆於交塘系之上；岩石以頁岩為主，時夾薄層砂岩，中上部夾有一公尺厚之石灰岩；故全層均易受風化侵蝕，成低坡小邱；上部常夾灰綠色灰質頁岩，具絲絹光澤，呈千枚狀；廣豐縣大南橋附近及玉山東鄉，又浙省江山縣豐足附近，均採有 Lower Arenig 筆石化石甚多，已鑑定者如下：

廣豐大南橋東五里 Loc. No 19 :-

*Phyllograptus anna Hall*

地質彙報

- Phyllograptus ilicifolius* Hall  
*Tetragraptus bigsbi* Hall  
*Tetragraptus phylloides*  
*Didymograptus extensus* Hall  
*Didymograptus hirundo* Solter  
*Didymograptus nicholsoni* Lapworth  
*Trigonograptus ensiformis* Hall  
*Dichograptus separatus* Eller  
*Mastigograptus circinalis*  
中台寮採集地 Loc. No 122  
*Tetragraptus bigsbi* Hall  
*Trigonograptus ensiformis* Hall  
*Glyptograptus*  
塔子沟三號採集地 Loc. No C3  
*Didymograptus extensus* Hall  
*Didymograptus hirundo* Salter  
*Phyllograptus angustifolia* Hall  
*Trigonograptus ensiformis* Hall

全層厚度，在廣豐大南橋東所測得者；計下部泥質頁岩夾砂岩層厚約三百公尺；上部黃色及綠色千枚狀頁岩為一百五十公尺；共厚四百五十公尺。

(三) 大南嶺石灰岩——出露於廣豐縣西北鄉之大南橋(第二版及第一圖)者為最完整，故名。整合覆于玉山頁岩之上，岩石以灰白色帶砂質之石灰岩為主，燧石甚少，常與棕黃色泥質頁岩互層，厚自數公分至數公尺不等。本系總厚為三百公尺，沿東北——西南走向分佈於大南橋東南，西南過大南嶺即被覆于武彝層之下，東北至秦村附近，阻於大斷層。玉山境內，僅零星露頭，斷落不續；縣城東北，鷄頭山等矗立小山，皆成自本系，又三都附近，亦有一本系石灰岩所成之小山，與禮賢煤系成斷層接觸。本系岩石，以大部為砂質石灰岩，故抵抗風化力較強，且植物難以滋長，常成矗立之青石山，甚易識別。本系據所採集化石鑑定結果，大致屬於下奧陶紀之最上部，其上部或屬於中奧陶紀之下部，茲將已鑑定化石有下列數種：

廣豐大南橋東十五里秦村西二里 Loc. No. Iri (屬本系之下部)

*Tetragraptus bigsbi* Hall

*Didymograptus extensus* Hall

*Trigonograptus ensiformis* Hal

玉山三都王家井西山 Loc. No. Irs (屬本系之上部)

*Orthograptus rugosus*

*Orthograptus truncatus* Lapw.

*Mesograptus foliaceus* Murchison

(四) 秦村系——整合覆於大南嶺石灰岩之上，為一種灰綠色灰質頁岩及黃棕色細砂岩之互層；本區域內，僅秦村附近露出，(第二版及第一圖)且其上部為大斷層所陷落埋沒，亦未覓得化石；惟依岩性及層次觀察，似相當於浙省硯瓦山系之下部。

(五) 飛來峯石灰岩——本區以構造上關係，奧陶紀以後，二疊紀以前地層，即浙省之豐足頁岩及千里崗砂岩，均以大斷層影響而付缺如。故飛來峯石灰岩，與其下岩層之接觸，均未見及，惟在浙江西南部所見，飛來峯石灰岩與千里崗砂岩為不連續接觸；至與其上禮賢煤系之接觸，在廣豐縣排山（第一圖）所見最為清楚，石灰岩之上，為一層富含腕足類化石之灰黑色頁岩，表示深海已變為淺灘，則此種動物羣隨即以環境驟變而死亡埋沒；再上為一層砂化甚深之燧石石灰岩，更上則為頁岩，繼以砂岩；故以理揣測，飛來峯石灰岩之與禮賢煤系，不過由海相而漸變為陸相，停積固無間歇，亦無侵蝕之象徵也。本層岩石大部為灰黑色灰岩，下部較純，上部砂質漸增多，茲將廣豐排山附近所見之層次及厚度，自下而上，排列如次：

(一) 灰色較純石灰岩，厚層，燧石甚少，土人用以燒石灰，其下岩層，被掩蓋而未出，所見之厚度為二十公尺。

(二) 黑色塊狀燧石甚多之帶砂質石灰岩，厚三十公尺。

(三) 燧石成層砂化更深之石灰岩，呈灰黑色，厚七十五公尺。

(四) 黑色燧石層，厚二公尺。

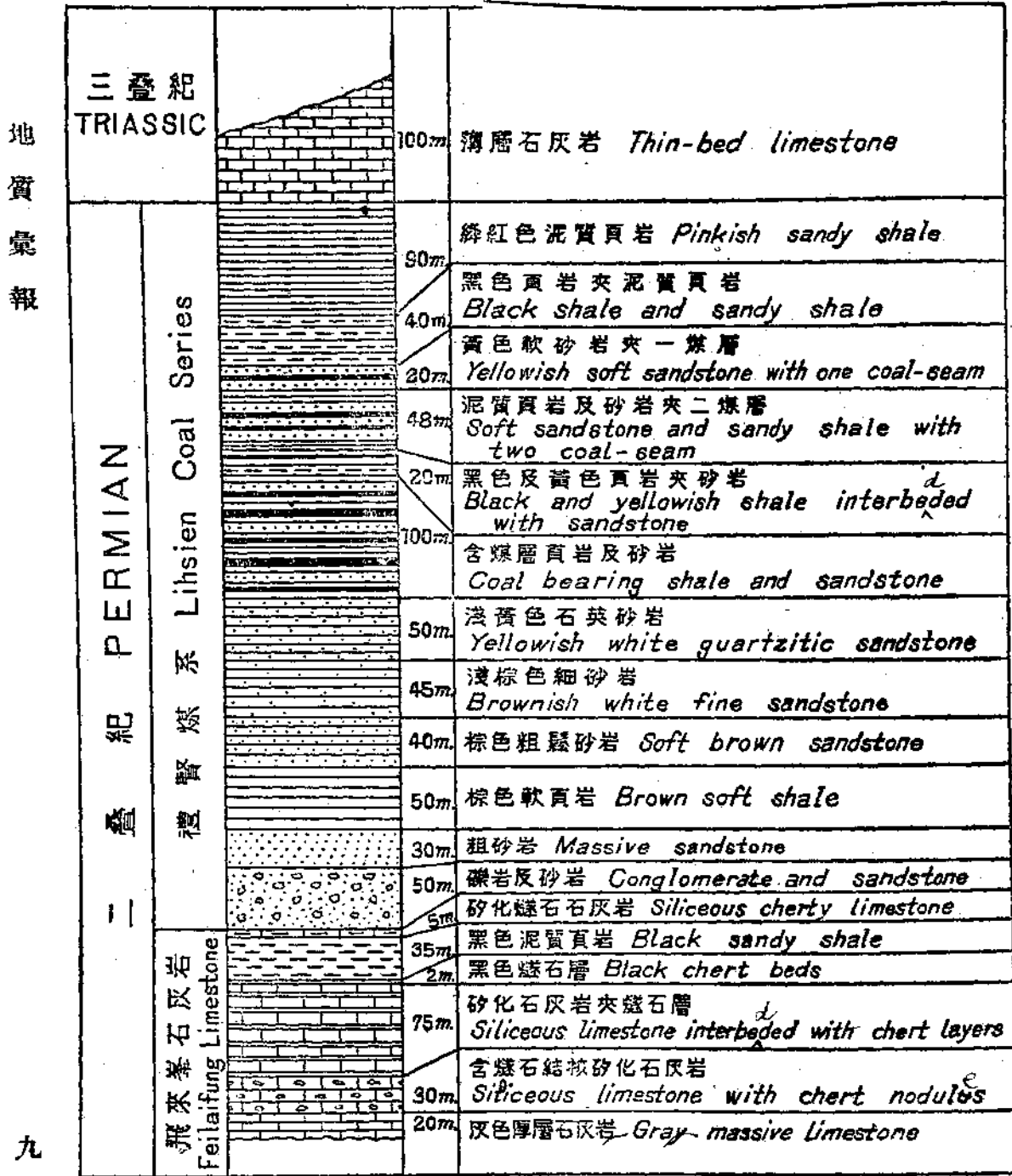
(五) 黑色泥質頁岩，風化面上呈黃色富含腕足類化石。厚三十五公尺。

(六) 砂質燧石石灰岩。五公尺。

本系分佈（第二版）於玉廣大斷層線以東，在廣豐縣境者，排山附近較為發育，該處受走向斷層所昇起，石灰岩成一陡坡，高近二百公尺，沿走向分佈，長凡十公里，露頭最為清楚；吳村北山，本系石灰岩倒置於禮賢煤系之上，為一逆掩褶皺，傾斜角最緩處僅二十餘度，施村附近，傾斜角漸變大，至玉山境內之路亭山，漸轉變而為順置；路亭山附近至三都一帶，本系石灰岩，褶皺起伏，故分佈甚廣，惟多被浮土所蓋，露頭斷落不續，東北行經八都屏山直至下鎮毛宅附近，本系石灰岩，亦常成一二百米突之山嶺。

(六) 禮賢煤系——本系以與劉趙二君在浙西江山縣禮賢鎮之煤系相連，故引用舊名。惟在江西境內，露頭較完全，厚度大

圖形柱田煤門排豐廣西江 圖三第



增，排門附近，厚度在六百米突以上，層序及各層厚度如柱狀切面（第三圖）。

禮賢煤系，在玉廣二縣分佈甚廣，尤以廣豐東北鄉及玉山東南鄉為最。一支自玉山東北鄉毛宅東山西南行經屏山，八都鎮，上宅，路亭山而至廣豐之吳村；一支自江山縣之禮賢官溪來，經廣豐之竹岩，湖口宅，社后而至排門，王家井及杉溪一帶；此外玉山縣尖山附近，煤系自成一背斜層構造；又廣豐與上饒交界處

之六十六都王坑煤田附近，亦有煤系露頭。總計本區煤系露頭，延長凡四十餘公里。

黑色頁岩中及煤層中，含二疊紀植物化石甚多；粗經鑑定者如下：

廣豐排門太陽山 Loc. No. 14

*Gigantopteris nicotianaefolia*

*Pecopteris anderssonii*

*Neuropteris* sp.

廣豐吳村西山 Loc. No. 110

*Alethopteris norinii*

*Taeniopteris latecostate*

廣豐石塘山 Loc. No. 16

*Cordaites* sp.

(七) 薄層石灰岩——本層僅見於廣豐城東北杉溪雙橋附近，為薄層（每層厚約三公分）砂質灰白色石灰岩，整合覆於二疊紀煤系之上；其上部未露出，就所見者言，厚約百公尺左右。此處未覓得化石，不過就岩性及層序推斷，應相當於蘇皖之眠牛石灰岩，亦即相當於湖北大冶石灰岩之頂部，而由於他處化石之證明為三疊紀。

(八) 武彝層——本系在昔劉趙二君調查浙西地質報告上，名其上部為流紋岩層，下部為建德系；十八年王恆升君調查京粵沿路所見，謂建德系遞積之始，火山即已開始活動，故主張將二系併而為武彝層；作者此次在贛東所見，亦復如是。全系岩層甚為複雜，一若北方之髻髻山系，流紋岩粗面岩安山岩塊集岩凝灰岩及砂岩頁岩等，一應俱全，以無一完整之剖面，故將各地所見者湊合推斷，約如下列層序：（自下而上）

安山岩

粗面岩

流紋岩(薄層結晶較細)

塊集砂岩夾凝灰岩

礫岩

紫色砂岩夾頁岩

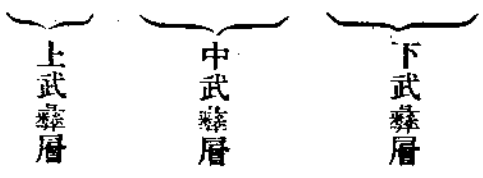
石英斑岩

流紋岩(厚度甚大結晶較粗)

由此可知中國東南部火山之爆發，最初為鹽基性岩漿洪流，次漸繼以酸性岩漿，旋轉入靜止狀態，以故砂岩頁岩亦乘機停積，迨後火山又大爆發而成掩蓋最厚分佈最廣之上部流紋岩及石英斑岩。

本區域內，因侵蝕較深，故遺留至今者，上部甚少，下部尚稱發達；廣豐兩石頭高山，山頂為中武彝層之赭色砂岩及頁岩，蓋此層抵抗風化力甚強，傾斜甚緩，僅十餘度至二十餘度；此種赭色砂岩，驟視之，極似衢江砂岩，惟較為堅硬緊密，前者屢見於高山頂，後者則常見於平地低坡；塊集岩礫岩等，則以玉山東南邊境最為發達，入都至新塘邊之汽車道旁，分佈廣及數百方里，蓋傾斜甚緩，普通僅十餘度。下武彝層分佈於廣豐東北鄉茅屋尖高山，東北行直至玉山江山二縣交界之雙峯尖，成一主要山脈，又廣豐上饒交界之壺橋附近，亦有下武彝層之粗面岩及砂岩凝灰岩所成之山脊。

本層與其下岩層，為不整合接觸，廣豐排門附近，本層岩石，覆於二疊紀煤系之上，煤系斜角為五十度左右，而武彝層僅十餘度；壺橋西南，本層又直接覆於下奧陶紀岩層之上。本層中部頁岩中，前劉趙二君曾在浙省壽昌縣境，覓得葉腳類之介殼類化石，似屬上白堊紀。





全層厚度，此次於浙贛邊境一帶所見者，當在一千公尺左右，而上部流紋岩尚祇見其一部分；故中國東南部白堊紀地層，停積之厚，分佈之廣，實足驚人也。

(九) 衢江赭色岩系——上部多為鬆軟之粗砂岩，下部多屬礫岩層；廣豐三十八都南山露出最為清淅，該處為斷層所陷，本系岩層，傾角大至四五十度，為他處所罕見；其層序及厚度如下：(自下而上)

- |                    |        |
|--------------------|--------|
| a. 赭色礫岩夾砂岩         | 一百九十公尺 |
| b. 紫色頁岩夾棕色砂岩       | 二十公尺   |
| c. 赭色砂岩夾礫岩(卵石多石英岩) | 二十五公尺  |
| d. 紫色頁岩            | 十公尺    |
| e. 赭色砂岩            | 二十五公尺  |
| f. 赭色粗鬆砂岩夾紫色頁岩     | 一百七十公尺 |

本系岩石，多露出於山麓或河流兩旁，率皆成低岡小丘，蓋自流紋岩掩蓋成高原之後，被河流所侵蝕而成若干盆地及河床，本系岩石，遂停積於是；以分佈於浙省衢江兩岸最為廣闊，故名；在本區內，均係零星露頭，僅玉山縣城西北出露較廣，餘如杉溪及信江支流兩岸，均有其零星遺跡。本系岩石，以便於採取，常用以舖路及作建築石料，臨河諸露頭，又便於運輸，開採甚盛；惟過鬆軟，不能堅固耐久也。

### 構造

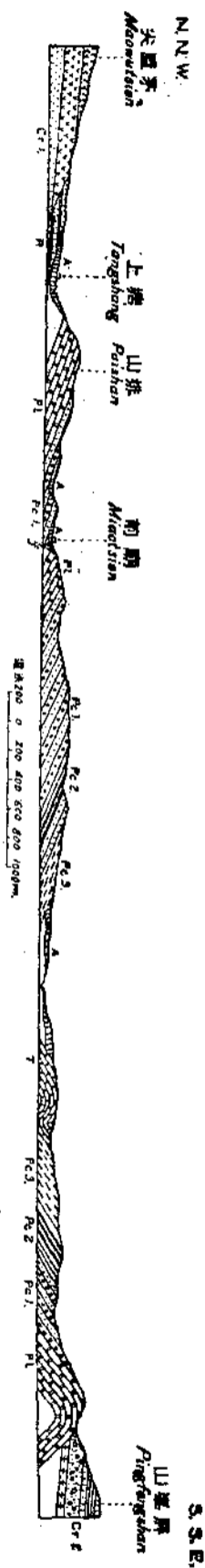
本區地質構造，略似浙西，地層走向及山脈，均作東北西南向，大斷層亦常作東北西南向；古生代地層，褶皺甚劇，白堊紀地層則傾角幾無過二十度者；可知本區之造山運動，尚在白堊紀以前，即所謂燕山運動也。茲分述如此次：

玉廣大斷層——縱斷玉山廣豐二縣(第二版及第一第二圖)，方向為北北東—南南西，北自玉山縣毛宅西，西南行經六都西山

及廣豐之秦村東山坡而至吳村西南為沖積層及赭色砂岩所掩蓋，斷層線凡三十公里，東部下降，西部上昇，縱斷距在一千公尺以上；故斷層線以西，均係較古之奧陶紀地層，斷層線以東，則為二疊紀及更新地層；斷層線最清淅處，為玉山縣三都王家井西山，二疊紀煤系，與下奧陶紀大南嶺石灰岩，各成一小山，二者均覺得可鑑定之化石，斷層線即經過此二小山所成之山溝。參閱剖面C C第一圖。廣豐吳村西南山，煤系亦為斷層所隔，而與奧陶紀岩層接觸，亦極清淅，惟武彝層露頭，雖無緊接斷層線者，而據觀察推斷，似未受此大斷層影響；故此大斷層發生時期，當在三疊紀薄層石灰岩停積之後，白垩紀武彝層停積以前。

冷水埧斷層—廣豐縣東北鄉排山附近，為一走向斷層，自王家井東北行經廟前及冷水塘而至獨角塘，沿山麓均為斷層線所經

圖面剖A A 田煤門排 圖四第



，西北方下降，該處地層係向東南傾斜，故二疊紀石灰岩及煤系均重複；參閱剖面A A第四圖。

三十八都斷層—廣豐三十八都南山北坡，二疊紀石灰岩成一二百公尺懸崖，山麓與第三紀之赭色岩接觸，且赭色岩之傾斜角大至四十餘度，為他處所未見；此種情形，赭色岩系之出露，似非僅河床之局部停積足以解釋；又二疊紀石灰岩，在本區域及浙省西南部一帶，露頭均斷落不續更未見有成山嶺懸崖者，而此處則東北起自官溪南山西南，沿大長嶺唐坑嶺石塘山井溫山排山而至仙岩山金雞嶺，延長凡十餘公里，石灰岩均成一二百公尺之陡坡；故可斷定沿山麓為斷層線所經過也。

桐家塢斷層—廣豐東北鄉桐家塢詹家塢一帶，亦為一走向斷層，二疊紀石灰岩重複露出，情形與冷水埧斷層相同，且或可相接連也。

武安山背斜層——玉廣大斷層線以西，奧陶紀地層，褶曲甚緩，由玉山武安山西南行經草鞋岑而至廣豐大南橋，大致為一背斜層，褶軸東北西南向，惟褶軸西翼多被武彝層及沖積層所掩覆埋沒；僅武安山西北坡有向西北傾斜之交塘系露頭；又橫街之交塘系露頭，似又為其西翼再經褶曲而出露者。

尖山背斜層——玉山三都尖山，為一背斜層構造，尖山高處雖為武彝層之下部不整合掩覆，而南西山麓，均有傾斜不同之禮賢煤系及斷落之飛來峯石灰岩露頭，大致均向山之東南及西方傾斜，為一以尖山為軸（北東東——南西西方向）之背斜軸，而向西南低落。

路亭山背斜層——玉山東南鄉路亭山附近，亦為一背斜層構造，褶軸與尖山背斜層大致平行，蓋係連續褶皺，二者之間為一褶曲甚緩之向斜層也，飛來峯石灰岩時隱現不常於褶軸附近，蓋輒為其本身風化而成之紅土所掩。此背斜層軸西南行至廣豐寨村東北山阻於大斷層，東北行至路亭山東北入於平地，而至屏山附近，又起而出露地表，褶軸為飛來峯石灰岩，兩旁有煤系露頭，惟褶軸已漸由東北——西南變為北北東——南南西，東北直至下鎮附近，被覆于武彝層之下。

吳村逆掩褶皺——廣豐吳村北山，飛來峯石灰岩逆覆於禮賢煤系底部之礫岩層上，傾向西北，斜角僅三十度左右，為一顯著之逆掩褶皺；參閱剖面 C C 見第一圖。東北行至施村附近，已漸變為順置矣。

雙橋向斜層——廣豐城東雙橋附近，為一向斜層構造，褶軸大致為北東東——南西西方向，三疊紀薄層石灰岩露出於褶軸附近，其旁則為二疊紀禮賢煤系，傾斜角均大，薄層石灰岩，所見往往為六七十度，否則，此向斜層所成之煤田，當有巨大價值矣。參閱剖面 A A 見第四圖。

### 礦產

#### 煤 總論

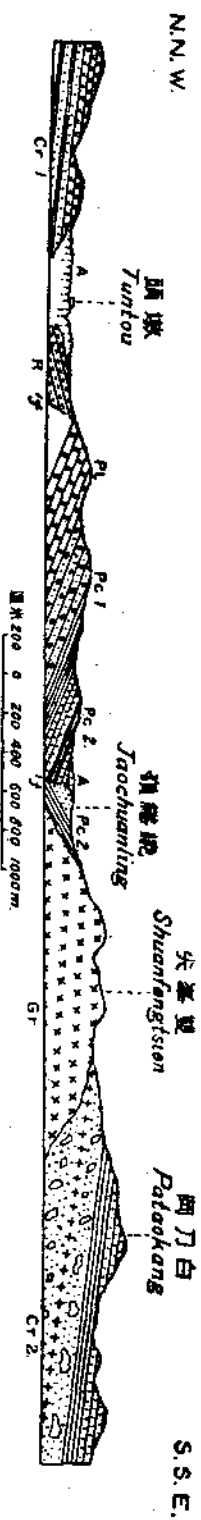
廣豐玉山二縣煤田，均屬二疊紀，煤層，與江山之禮賢煤系相同，在長江流域分佈甚廣，廣豐境內，化石甚為豐富，有大葉

羊齒類等。廣豐東北鄉，及玉山東南鄉，煤系地層，最為發育，廣豐西北與上饒交界之王坑，煤系亦露出地面，又廣豐之南鄉，昔出煤甚豐，近以其匪盤踞，無法調查，煤質，以無烟煤為主，廣豐排山附近之橫山港，及玉山三都塘埕一帶，為烟煤，八都至吳村一段，謂亦係烟煤，惟停工已久，無法採取煤樣，待將來鑽探或採掘所得始能確定。煤之貯量，據計算結果，總數約在二千三百萬噸以上，惜傾斜甚陡，且煤層厚薄無定，經濟上似不宜於大規模開採也。茲分述如下：

廣豐排門一帶煤田

位置——排門位於廣豐城之東北，離城三十餘里，煤田向東北西南延展，長凡四十餘里，分為數支，包有竹岩，湖口宅，社后

圖五 剖面 B B 田 煤 門 排 圖 五 續



，七七嶺，梅樹底，排門橫山港，王家井，杉溪等煤田。參閱第一版。

交通——廣豐東北鄉，河渠雖多，但均不能通船隻，僅杉溪自東南來，流經杉溪村，西山底而至廣豐縣城，可通小船，西行至上饒而入信江，自此至九江，大船暢行。自礦區至杉溪或西山底，陸路自數里至三四十里不等，或由陸路至江山縣之鳳林鎮，下文溪，可通木筏或小船，至清湖鎮易大船下運至杭州。計礦區至鳳林鎮，最近處約二十里，陸路運輸，端賴人力，故運費亦甚昂貴，普通每百斤每華里需費一分八厘，現公路完成者甚多，衢廣路（衢州至廣豐）繞於西北，玉杉路（玉田至杉溪）通於西南，峽楓路（淤頭至楓嶺）經其東，距汽車路最遠處亦不過三十餘里。惟汽車運輸，固甚迅速，而運費與人力不相上下，故亦未見以

汽車運煤者。杭江鐵路金玉段將告成，將來本區所出之煤，可由陸路至新塘邊，（相距二十里至四十餘里）由鐵路運銷滬杭。

煤層——煤層夾於二疊紀煤系中部，因未經大礦開採及探鑽，故煤層厚度及層數未能確實斷定。就各窰戶歷來所採之經驗，謂共有煤層九，煤層間距離自一二公尺至數十公尺不等，且同一層間，相距亦隨地而異。排門橫山港一帶，大致可供開採者凡二，每層最厚處有達五六尺者，薄者僅數寸，隨地變化無定，普通以二三尺者為多。社后七星廠所開之煤，有二層，每層厚度自四五寸至二三尺不等。竹岩長和蓬所開者，平均厚約二尺。煤層傾角大致均陡，自五十度至八十度不等。

煤量——本區煤田，對於地質構造及煤層分佈，雖經作者詳細觀察，惜以無大礦開採及鑽探，煤層厚度及層數，未能確實斷定，故對於估計煤量，諸多障礙，但為粗悉煤量之多寡，藉定煤田之價值計，惟就已知之事實，加以推測，以求近似之煤量。本區煤脈之分佈，因斷層及褶皺關係，大致分為四支。一自江山南塢來，經竹岩，湖口宅，社后，柴裏而至洞門底，在廣豐境內，露頭延長凡五公里，煤層傾向東南，斜角頗大，約六十度左右，故向下探掘，不能過深，假定距地面三百公尺以上之煤可以經濟的方法採取，則煤層可採之寬度，不過三百五十公尺，煤層總厚，按社后竹岩所開得者計算，平均約為四尺，即一·三公尺，煤屬無烟煤，比重以一·三計，則貯量約為三百萬噸。一支起自梅樹底，經獨角塘而橫山港以至王家井，延長凡六·七公里，煤層傾向東南，傾角自三十度至七十度不等，平均可開採之寬度為四百公尺，平均總厚度為一·四公尺，則貯量為三，七五二，〇〇〇噸。排門太陽山一支，西迄黃村凹，長凡四·六公里，此段露頭較完善，小窰業亦最盛，煤層傾向南稍偏東，傾角平均六十度左右，煤層平均總厚為一·五公尺，貯量計為三，一三三，〇〇〇噸。杉溪一支，長四·八公里，惟一部覆於武彝層之下，煤量約為二百萬噸。綜計排門一帶煤田貯量之總數，約為一千二百萬噸。除土窰已採去部分及工程上不能完全採去之部分，若以十分之七為可採之煤量，則開至離地面三百公尺深度為止，總得可採煤量為八百四十萬噸。

煤質——多屬無烟煤，僅橫山港裕興所出者為烟煤，會煉焦炭，所採各地煤樣，經本所沁園燃料研究室化驗部分析結果，列表如下：

採集號數	分析號數	地點	水份	揮發物	固定炭	灰份	發熱量	粘性	分類名稱	記號
5	864	江西廣豐橫山港	0.55	19.70	63.6	16.30	7230	粘微膨	高烟	Bh
6	865	廣豐大樹塢	1.35	8.55	82.5	8.55	5700	不粘	低烟	Al
7	866	廣豐排門冷水塘	1.35	9.0	77.7	13.7	7550	不粘	低烟	Al
8	867	廣豐社后	4.00	6.55	80.55	9.10	7690	不粘	無烟	Al
9	868	廣豐竹岩	3.35	7.35	75.6	13.5	7530	不粘	無烟	AB

礦業—玉山廣豐二縣，現今以排門一帶礦業較盛，但均係小窰業，一切均賴人工，即抽水亦用最簡笨之木桶汲取，每年夏季雨水大時，率告停工，採掘方法，亦至為簡陋，故工人多而出煤少，加以該地歷受匪患，生產率減少，糧食昂貴，故工價提高，而成本隨之加重。本地每百斤售價三角至四角。運費亦高，挑至河畔下船，陸程二十里，每百斤挑力需費三角，故運至外地，煤價每百斤總在七八角以上。煤礦之較大者，排門之寶盛廠，大豐廠，和豐廠及同氣廠，每日出煤均在萬斤以上，橫山港王家井一帶，有勤益，裕豐等廠，裕豐在昔出煤甚多，且係烟煤，自行煉焦，後為水所掩，元氣大損，至今尚未恢復。勤益廠等每日出煤約五六千斤。社后竹岩一帶，有七興廠，長和蓬等，每日出煤約六千斤。故排門一帶，雖無稍具規模之煤礦，但小窰林立，不下三四十處。出煤總數，亦具可觀。所出之煤，銷路甚廣，廣豐玉山二縣，木柴不多，故煤價雖高，大都仍樂用之。將來如能稍具規模，集中開採，用抽水機及簡單機器以代人工，築輕便鐵路以利運輸，則煤業頗有望焉。

#### 玉山東南鄉煤田

位置—煤田為一東北西南向之狹長區，位於玉山縣之東南部，距縣城最近處約二十里，南與廣豐縣相接，並伸出一部於廣豐之吳村附近。就大體言，煤田為一背斜層所構成，斜軸在屏山附近可以見及。東翼南起自廣豐之吳村，東北行經玉山縣之施村，路亭山，前塢，上宅及八都附近之大路新澤，再東北行則斷落不續，直至下鎮南祝家莊附近入於平地，再東則為火山岩所掩覆。

西翼東北起自上塢，經毛宅東山神仙洞而西南行，亦斷落不續，大部入於平地，至尖山附近，復行露出。尖山自身又為一背斜層構造，故尖山之東西南三面，均有煤系出露，再西南行阻於斷層，而與奧陶紀石灰岩接觸，總計東翼煤系，延長凡二十四公里，露頭可踪跡者約占五分之三。西翼延長凡二十八公里，露頭之可踪跡者僅占三分之一。參閱第二版。

交通—玉山東南鄉，無可通舟楫之河流，運輸全賴人力挑載，至玉山縣城，始能下冰溪，通運九江，現杭江鐵路金玉段即將完成，下鎮六都鎮皆為鐵路線所經，故將來交通上當極便利矣。

煤層—煤層與廣豐排門一帶者大致相同，蓋出自同系同層，相距亦不遠，不過以褶皺及斷層關係而分隔耳。玉山東南鄉煤田，以交通不便及水患種種關係，開採者極少，故從事調查煤層之厚薄及層數，殊覺困難。據路亭山煤礦開採者言，煤層亦為九層，惟可供開採者僅上下二層，上層厚度自數寸至二尺不等，下層厚度有達八九尺者。三都附近所開烟煤，厚僅尺許，惟亦曾見有三四尺者。毛宅東神仙洞，在昔曾掘有四五尺之煤層，後以水患而停工。

煤量—玉山東南鄉煤田構造，大致為一背斜層，西以大斷層與奧陶紀之大南嶺石灰岩接觸，東端則被覆於火山岩系及赭色岩系之下，煤田向東北西南延展，最長處約五十餘里，（自玉山大塢至廣豐吳村）最寬亦有十餘里。煤層自八都之大路，新澤以迄吳村一段，露頭尚完整，吳村路亭山前塢上宅等處均經採掘，走向大致為北西南，吳村施村一段，為逆掩褶皺，傾向西北，飛來峯石灰岩，逆覆於其上，斜角為三十度左右，過施村斜角漸大，至路亭山漸變為順置，經前塢，上宅直至八都附近，傾向東南，斜角仍大，普通約六十度左右，煤層厚度，據所採經驗，大致平均總厚為〇·八公尺，八都至吳村一段，延長凡十二公里，可採之寬度平均為三百五十公尺，則煤之貯量為四，三六八，〇〇〇噸。毛宅東神仙洞一帶，據前人開掘經驗，煤層之可供開採者亦為二層，上層較薄，下層自數寸至五六尺不等，故假定其平均總厚亦為八公分，則煤之貯量為二百五十萬噸左右。至三都尖山附近，煤田構造，為以尖山為軸之背斜層，而向西南低落，故尖山東西南三面，均有其斷續露頭，再西則阻於斷層，露頭延長凡四公里，據三都王村塘塢所開者，厚度自一二尺至三四尺不等，斜角為二十度至三十餘度，陳家塢前所開者厚度有四五尺者，傾斜

角均不大，不過與大斷層相近處，其下煤層不知有否受其影響，尙難預料，約計尖山附近一段，煤量爲三百萬噸左右。此外六都附近及下鎮迤西一帶，均有零星煤系露頭，估計本區煤量總數，約爲一千一百萬噸。今以七折計算，則實際可採煤量爲七百七十萬噸。

煤質—本區煤田，現今開採者極少，僅三都附近有小土窰，茲將該地所取煤樣，經沁園燃料研究室化驗部分析結果，列表如下：

採集號數	分析號數	地 點	水 份	揮 發 物	固 定 碳	灰 份	發 熱 量	粘 性	分 類 名 稱	記 號
11	869	玉山三都塘埕	1.11	10.5	50.6	3.04	6.5	粘微膨	中烟	Bm
12	870	玉山三都陳家塢	1.00	18.00	51.9	41.10	5.35	粘微膨	中烟	Bm

礦業—玉山東南鄉甲現今無礦業可言，調查所經，僅三都王村塘埕有一小窰，工人不足十名，每日出煤不過數百斤。惟舊洞殘窰，觸目皆是。蓋玉山東南鄉，交通至爲不便，運輸端賴人力，地下水又常爲患，非小窰業所能經營。而近年來受共匪直接或間接影響，稍有資產者均遠走他鄉，何能集資興辦礦業。杭江鐵路通玉山後，本區煤田離鐵路線尙近，將來運輸便利，盜匪難逞，煤業或因以興焉。

#### 「附」石煤

與陶紀之最下部，爲一種含炭質甚多之板狀黑色頁岩，土人取名曰石煤，蓋意謂介於煤與石之間也。本地專供燒石灰之用。石煤層之上，爲黃色砂岩，再上卽爲石灰岩，此三者均歸於交塘系。故凡交塘系分佈之區，皆有石煤及石灰岩之露頭，亦卽石灰窰林立之區也。廣豐之交塘，玉山之草鞋岑，及屏風關，橫街等處，均爲石灰業發達之區，石煤之厚度，在廣豐交塘所見，可供燃燒者凡十公尺。以此計算，本區露頭延長凡三十餘公里，則貯量在三萬萬噸以上。本地售價每噸值一元左右。惟此種石煤，不能以貯量計其價值，蓋經濟上既不能運輸他方，又難作其他用途，全視本地之石灰業爲銷場也。玉山橫街所出之石煤，經本所沁



國燃料研究室化驗部分析結果如下：

水份——四·四五

揮發物——五·二二

固定炭——一三·五三

灰份——七九·八〇

發熱量——一六三一

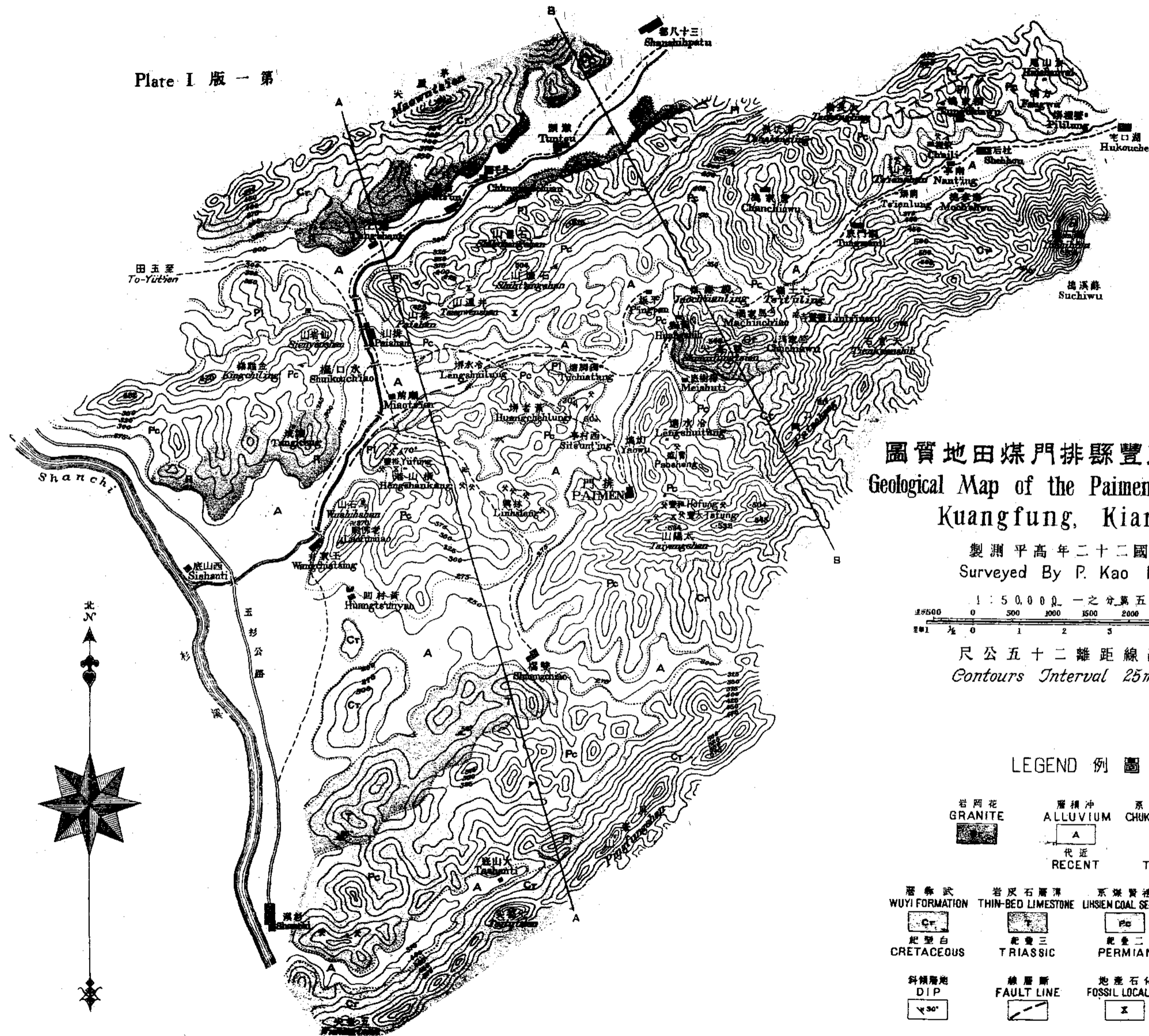
粘性——不粘

分類名稱——中碳烟礫

記號——Bm

石灰

重要之石灰產地，大致與上述之石煤產地同，蓋燃料之成本輕，而石灰易發達，玉山草鞋岑，每百斤僅售大洋三角，至石灰石之材料，下奧陶紀之石灰岩，並不過純，有時泥質甚多，須加以挑揀，始能燒灰，此外廣豐東北鄉，亦有用二疊紀石灰岩燒灰，燃料則取給於二疊紀之無烟煤，故成本較高，僅供本地之用，不能與上述之石灰窰相抗衡也。



圖質地田煤門排縣豐廣省西江  
Geological Map of the Paimen Coal Field,  
Kuangfung, Kiangsi.

製測平高年二十二國民  
Surveyed By P. Kao 1933.

1 : 50,000 一之分第  
0 500 1000 1500 2000 2500 3000m.

尺公五十二離距線高等  
Contours Interval 25 meters

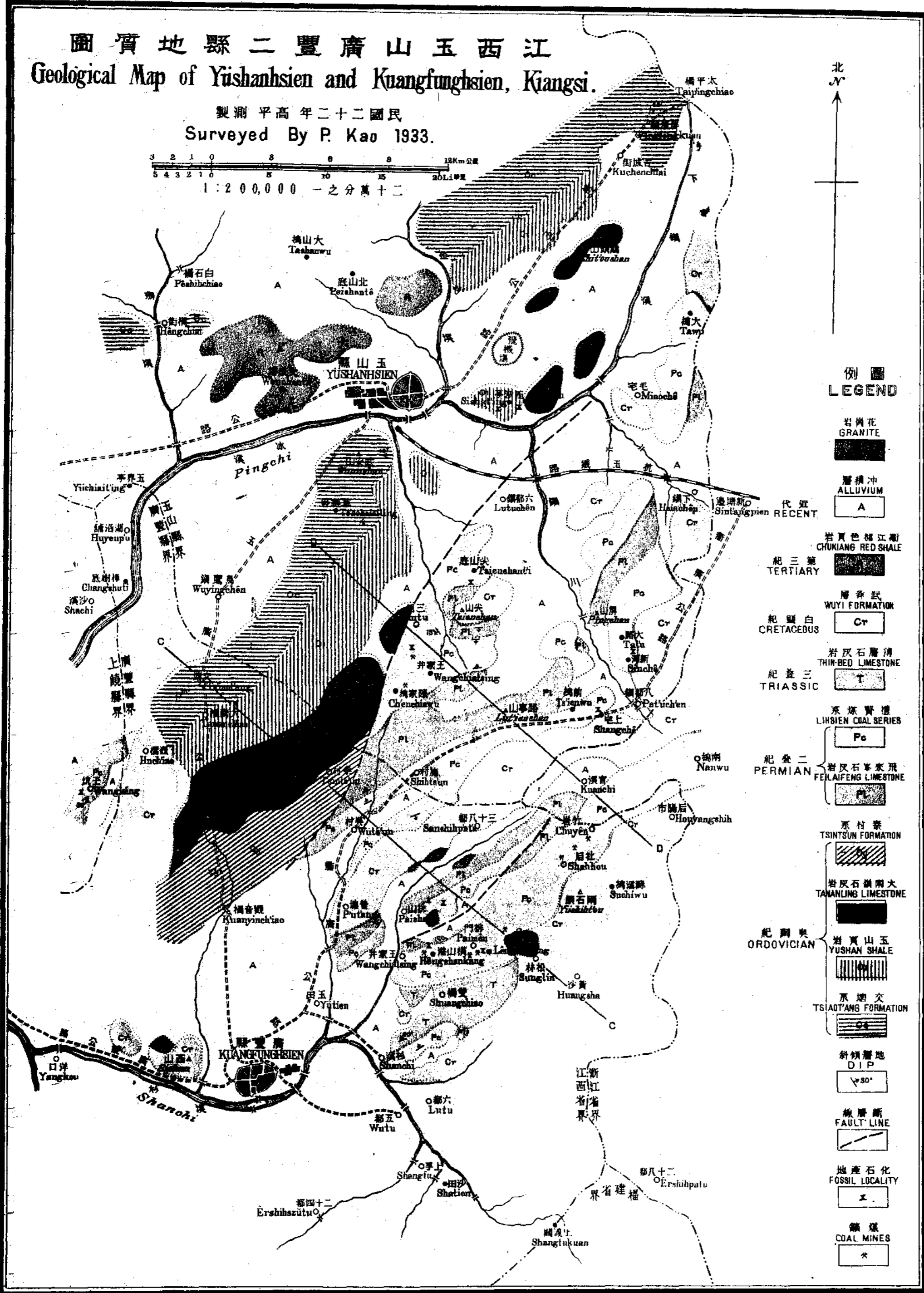
LEGEND 例圖

岩岡花 GRANITE	層積冲 ALLUVIUM	系岩色紅江衛 CHUKIANG RED BEDS	
	A		
	代近 RECENT	紀三第 TERTIARY	
層蘇武 WUYI FORMATION	岩灰石薄 THIN-BED LIMESTONE	系煤寶禮 LINSIEN COAL SERIES	岩灰石華東 FEILAI FENG LIMESTONE
Cr		Pc	Pt
紀白 CRETACEOUS	紀三 TRIASSIC	紀二 PERMIAN	紀二 PERMIAN
斜傾地 DIP	線層斷 FAULT LINE	地產石化 FOSSIL LOCALITY	礦煤 COAL MINES
30°		X	*

# 圖質地縣二豐廣山玉西江 Geological Map of Yüshanhsien and Kuangfungsien, Kiangsi.

製測平高年二十二國民  
Surveyed By P. Kao 1933.

1:200,000 一之分萬十二



北  
N

## 例圖 LEGEND

- 岩崗花 GRANITE
- 層積沖 ALLUVIUM A
- 岩頁色紅江衛 CHUKIANG RED SHALE
- 紀三第 TERTIARY Cr
- 層非武 WUYI FORMATION T
- 紀白白 CRETACEOUS Pc
- 岩灰石層薄 THIN-BED LIMESTONE
- 紀三第 TRIASSIC
- 系煤腎禮 LIHSIEN COAL SERIES
- 紀全二 PERMIAN
- 岩灰石峯來飛 FEILAI FENG LIMESTONE
- 系村泰 TSINTSUN FORMATION
- 岩灰石嶺南大 TANANLING LIMESTONE
- 紀奧奧 ORDOVICIAN
- 岩頁山玉 YUSHAN SHALE
- 系塘交 TSIADTANG FORMATION
- 斜傾地 DIP
- 線層斷 FAULT LINE
- 地產石化 FOSSIL LOCALITY
- 礦煤 COAL MINES

版三第 頁 東 地 層 柱 形 圖  
 Plate III GENERALIZED COLUMNAR SECTION OF EASTERN KIANGSI

第三紀 TERTIARY	新江紅色岩系 Chukians Red Series		250m.	鬆砂岩及頁岩 <i>Soft sandstone and shale</i>
			180m.	鬆砂岩及礫岩 <i>Soft sandstone and conglomerate</i>
白堊紀 CRETACEOUS	武彝層 Wuyi Formation		350m.	流紋岩及石英斑岩 <i>Rhyolite and Quartz porphyry</i>
			400m. 500m.	塊礫岩, 凝灰岩, 砂岩, 頁岩及流紋岩 <i>Agglomerate, Tuff, Sandstone, shale and rhyolite</i>
			200m. 300m.	粗面岩 <i>Trachyte</i> 安山岩 <i>Andesite</i> 砂岩 <i>Sandstone</i>
			100m.	不整合 <i>Unconformity</i> 薄層石灰岩 <i>Thin-bed limestone</i>
三疊紀 TRIASSIC			90m.	微紅色頁岩 <i>Pinkish sandy shale</i>
二疊紀 PERMIAN	理賢煤系 Lih sien Coal Series		228m.	含煤層頁岩及砂岩 <i>Coal bearing shale and sandstone</i>
			265m.	砂岩及礫岩 <i>Sandstone and conglomerate</i>
			167m.	含矽質石灰岩 <i>Siliceous limestone</i>
	飛來峰灰岩 Feilairfung Limestone			斷層接觸 <i>Fault contact</i>
奧陶紀 ORDOVICIAN	桑村系 Tsintsun Formation		100m.	綠色及黃色砂岩及頁岩 <i>Green and yellowish shale and sandstone</i>
			280m.	石灰岩及頁岩 <i>Limestone with shale parting</i>
	大南嶺灰岩 Tananling Limestone		150m.	黃色及綠色千枚狀頁岩 <i>Yellowish and green phyllitic shale</i>
			300m.	頁岩及砂岩 <i>Shale and sandstone</i>
	文塘系 Tsiatung Series		80m.	泥質石灰岩 <i>Impure limestone</i>
		175m.	黃棕色薄層細砂岩 <i>Fine sandstone</i>	
		100m.	黑色板狀含炭質頁岩 <i>Black bituminous shale</i>	

# 華煤中硫質種類之分析

楊珠瀚

## (一)緒言

近世鋼鐵事業盛興，而焦煤 (Coking Coal) 遂見重于世。蓋焦煤云者，謂可供煉焦 (Coke) 之煤也。然完善之焦煤，頗不多觀。缺乏粘性者有之，灰份過高者有之。即或粘性強，灰份低，則又以硫份稍多之故，亦每為煉焦者所屏棄。然硫之性質不同。有時有可以人力減低其含量者。則雖有較高之硫份，仍不失為良好焦煤，故未可偏廢也。中國煤礦雖富而煉焦之煤則殊非甚多。其中所含硫份之性質尤向未有詳細研究。著者特就重要烟煤十五種詳加分析。費時半載，始告厥成。于中國焦煤問題或能有少補乎。

## (二)煤中硫質之分類

焦炭內之硫質，係由原煤而來。是以原煤中之硫質及其成分，關係于焦炭者，至密且巨。因撰是節，茲將煤中硫質之分類以及炭化 (Carbonization) 作用影響於焦炭中之硫質及其成分者，簡述如次：

I 基於化學性質之分類，亦即本篇之藍本也。

- a. 硫與碳，氫，氧，氮或磷諸原素，形成含硫之有機化合物，是為有機硫質 (Organic Sulphur)。
- b. 硫與鐵經化合而成為二硫化鐵，是為硫鐵礦硫質 (Pyritic Sulphur)。
- c. 硫礦硫質再經化學作用，轉變為硫酸亞鐵 (Ferrous Sulphate)，是項硫酸亞鐵同極少量之硫酸鈣 (Calcium Sulphate)，合稱硫酸硫質 (Sulphate Sulphur)。

煤中之硫酸硫質，大抵含量不高，似不致顯著的影響于煉焦，茲從略。二硫化鐵則又以其比重較大，大抵能以沖洗法 (Washing Process) 或浮游法 (Flotation Method) 削減或分除之。且是項硫質，於煉焦爐中，經分化作用變為一硫化鐵 (Ferrous Sulfide)

及原質硫 (Elementary Sulphur)。後者經再度化學作用，成硫化氫 (Hydrogen Sulphide) 而揮發。其一硫化鐵則轉變為易揮發之二硫化炭 (Carbon Disulphide)，或少量不易揮發之含硫有機物。蓋後者可由焦中硫化硫份之減低，及有機硫份之增高，而得證實焉。總之是項硫鐵礦硫質，確能以相當方法，減低其含量，則毫無疑問矣。是以焦煤中之硫質，其於焦炭之硫份，所最舉足重輕者，厥惟有機硫質耳。且後者含量既高，化除亦難。或謂此項硫質，亦能於煉焦爐中，分解其一部而揮發。蓋全部有機物質，就廣義言之，皆屬於揮發物質故也。然證諸事實則有大謬不然者。前已言之：即硫鐵礦硫質，經炭化作用，而成有機硫質是也。著者以為炭化作用，與其謂減低有機硫份，毋寧謂增加該項硫份之為愈耳！究以衆說紛紜，莫衷一是。是故有澈底測驗之必要。茲有下列分類。

II 本分類係小規模之煉硫試驗。其子目如下。

a. 揮發硫質 (Volatile Sulphur)。—此項硫質，以其能揮發於煉焦爐中，故不甚為害。就煉焦觀點言，此項硫質愈多則減低該焦炭之硫份愈易。

b. 固定硫質 (Fixed Sulphur)。—是項硫質與實用分析中之固定炭同一意義，即由全硫份減去揮發硫份及不燃燒硫份（灰內之硫份）之和。是類硫份之鑑定於含高量硫份之焦煤最關密切，亦絕對必要。設某煤含硫過多時，則繼以固定硫份之鑑定，以明其炭化後之是否減低其硫份，抑減低至何種程度，而決定各種硫質之鑑定，以及沖洗浮沈諸法之應用是否必要。匪特此也，由此鑑定亦可概見各焦之粘性硬度等，是故著者以為是項工作對於煉焦堪稱首要。此次惜以時間關係未得向此方研求不無遺憾。

### (三) 本試驗所選之煤樣說明

本試驗所選之煤樣，係採自中國南北各重要之烟煤礦。大多數可以煉焦。所選計十有五種，要亦可進窺中國一般焦煤對此各種硫質之存在，及成分之梗概焉。茲將所選之煤樣，詳實表出之如後：

表一——煤樣之來源及其類別

試驗室號數	省份	縣名	產地	煤礦	俗名或煤層	種類符號	時代
三〇六	山東	博山	西河岳家莊	同興公司	小石炭	AB	二疊石炭紀
三一九	河北	磁縣	西佐村	怡立公司	頭煤	Bm	二疊石炭紀
三二一	河北	磁縣	西佐村	怡立公司	一坐煤	Bh	二疊石炭紀
三四九	察哈爾	宣化	玉帶山絲溝	厚豐公司	甲號(全層)	Bl	侏羅紀
三六二	河北	井陘	崗頭村	井陘礦務局	南大井第五層	Bm	二疊石炭紀
三六五	河南	安陽	六河溝	六河溝煤礦		Bm	全上
三六九	山東	嶧縣	棗莊	中興煤礦	已洗煤末	Bm	全上
三七三	河北	灤縣	趙各莊	開灤礦務局	洗煤	Bm	全上
三七四	河北	灤縣	趙各莊	開灤礦務局	特別洗煤	Bm	全上
四四八	安徽	宣城	大汪村	水東官礦	烟煤	Bl	全上
四八五	安徽	懷遠	舜耕山	淮南礦務局	三四號井南三槽	Bc	二疊紀
五二三	山西	大同	口泉格格塔			Bl	侏羅紀
五九一	湖南	湘潭	譚家山	有利公司		Bh	二疊紀
五九七	浙江	長興	大煤山	長興煤礦	大煤山樣	Bc	全上
六五五	江西	萍鄉	安源	萍鄉煤礦	洗統煤	Bl	侏羅紀

表二——各煤之實用分析及發熱量

地質彙報

試驗室號數	水份	揮發份	固定炭	灰	份	公熱單位	英熱單位
三〇六	0.51	16.81	73.26	8.73	79.6	1406	
三一九	0.51	11.10	73.10	6.87	82.5	1404	
三二一	0.33	11.10	73.23	4.46	82.7	1401	
三〇九	1.26	15.01	67.5	3.64	76.3	1401	
三三三	0.14	11.70	75.01	11.15	83.3	1412	
三三〇	0.82	11.7	70.7	15.02	83.5	1412	
三三六	0.80	11.7	61.8	6.80	75.0	1416	
三三三	0.31	11.4	70.7	10.5	83.5	1414	
三四四	0.26	11.7	75.2	13.5	89.3	1404	
三四六	0.10	11.6	76.6	12.6	89.2	1412	
三四五	1.11	15.3	67.2	13.9	83.4	1413	
三四三	1.03	15.2	75.1	4.5	89.7	1402	
三五二	0.24	11.0	70.6	8.2	83.4	1413	
三五七	0.82	11.8	73.1	10.3	81.0	1414	
六零	0.21	11.6	73.0	15.2	81.2	1412	

(四)各種硫質之鑑定



a. 全硫份之鑑定，由來已久，方法亦夥。要皆不外以相當之氧化劑，使煤中之全部硫質成爲硫酸基 (Sulphate Radical)，而鑑定以氯化鋇焉。茲將其最重要之方法摘錄之如下：

1. 愛氏法 (Eschka method)。—以愛氏混合劑 (Eschka mixture) 燒之。後者係由一份之無水碳酸鈉二份之養化鎂及五份一份之硝酸銨三者混合而成。

2. 過養化鈉法 (Sodium Peroxide method)。

3. 氧氣法 (Oxygen Bomb washing method) — 養氣法定量似不甚精確，過養化鈉法亦覺不甚適用，最近又有人以養化鈣代替愛氏混合劑中之養化鎂。就經濟觀點言，意至善矣。但以尙無充分之證實，著者遂不得不依舊沿用愛氏之法。

b. 硫質分類之鑑定，以鮑氏及巴氏法 (Powell and Pam method) 爲最重要，亦最準確。著者於後部之分析，亦一本此法。

## II 試驗法

a. 全硫份之鑑定 — 先以三克之愛氏混合劑，盛於一適當之乾鍋或蒸發皿內；繼之以一·三三六克之煤末而攪勻之；再以一或二克之愛氏混合劑覆於其上。如吾人確知某煤含硫過多時（超過百分之二），該煤末宜減半用之。即〇·六八六八克是也。而上層之愛氏混合劑，則應加倍覆之。蓋恐硫質之不及養化而揮發，致結果低於實際之硫份也。將此乾鍋置於電爐內，漸漸燒之。以鍋內黑色之炭質完全揮發爲度。如無電爐，燒以無硫焰之氣燈或酒精燈，亦無不可。此殆視試驗室之設備而定耳。該鍋內之混合物，俟冷卻後取出研碎之，傾於摺就之濾紙上，沖以熱水至濾液之體積約達二百立方公分 (cc)。傾入此濾液以二或三立方公分之溴水 (Bromine water)，繼之以充分之鹽酸，使其酸化後，煮沸之。一俟溴氣全部揮發，即以十立方公分之氯化鋇 (百分之十)，漸漸滴入該沸騰之濾液內，頻攪以玻璃棍 (Glass Rod)。使沸騰約五分鐘，將該杯置於暖處渡夜，而以定量濾紙濾之，先洗以淡鹽酸 (百分之一)，繼之以熱水者約六次，或以無氯基 (Chloride Radical) 爲度。此項濾過之沈澱，置於精確秤過之乾鍋內燒之。硫酸鋇之克數乘以十即得該煤之全硫份 (百分比)。其用〇·六八六八克者，須乘以二十方可。

b. 全無機硫份之鑑定——煤內之硫磺硫質與硫酸硫質合稱為無機硫質。是項硫質能全部溶解於淡硝酸中，而有機物質則否。故依施氏及巴氏法，前者易於鑑定之如次：

一克之煤末置於百五十立公分之燒杯內，傾入以八十立公分之淡硝酸，（酸比水為一比三）而攪勻之，隨時攪以少許之溴水，於二十四小時後濾之。而置該濾紙及未被硝酸溶解之煤末於該原燒杯內，以備後部全有機硫份之鑑定。而於此濾液內，加入少許之濃鹽酸，置諸蒸汽鍋（Water Bath）上蒸發之使乾。而將此乾燥物，溶解於二十五立公分之水，及五立公分之鹽酸中，繼以熱氫氧化水（Ammonium hydroxide）使該酸液內之鐵質沈澱而後濾之。由此沈澱，鑑定鐵份以高錳酸鉀法（Potassium Permanganate Titration）。此項鐵份即為硝酸鐵量（Nitric Acid soluble Iron）。同時由該濾液中，鑑定硫份，一如前述。惟所得硫酸銀之重量，須乘以一三·七三六，始得該煤之全無機硫份。

c. 硫酸硫質之鑑定——煤內之硫酸硫份大都甚低。新出井之煤樣，甚至缺乏是項硫質。其出井時間較久者，則受外界之養化作用，形成少量之硫酸硫質。茲將此項硫質之鑑定法，簡述之如後：

置五克之煤末於五百立公分之燒杯或同容量之大口三角玻璃瓶（Wide Mouthed Erlenmeyer Flask）內，傾入以三百立公分之淡鹽酸（百分之三）而攪勻之，置於溫度約達六十度之電熱鐵板上，使其浸蝕，四十小時後濾之。由此濾液內鑑定鐵量及硫份，一如前述。而以所得之硫酸銀乘以二·七四七二，即為該煤之硫酸硫份。該鐵份則為該煤之鹽酸鐵量。

d. 硫磺硫份之鑑定——此項硫份之鑑定方法有二：

1. 由全無機硫份減去硫酸硫份即得。

2. 由硝酸及鹽酸溶液中之鐵量，計算得之——硝酸鐵份（Nitric acid Soluble Iron）減去鹽酸鐵份（Hydrochloric acid Soluble Iron）乃為鐵含於二硫化鐵內之鐵量。由此鐵量，與二硫化鐵之公式（ $FeS_2$ ），即可得相當於該鐵量之硫份焉。是為硫

磺硫份。

e. 全有機硫份之鑑定——全有機硫份之鑑定方法亦有二：

1. 由全硫份減去硫酸硫份及準確硫磺硫份之和，即為全有機硫份。

2. 以直接方法鑑定之。法以前經硝酸侵蝕而未溶解之煤末及濾紙，一併置諸該原燒杯內，加以足量之濃硝酸，置諸蒸氣鍋上乾之，約三四次。再加以濃氫氧銻水於該乾燥物上，攪勻而後濾之。該濾液經再度乾以蒸氣鍋，而以愛氏法鑑定該乾燥物內之硫份焉。所得之硫酸銻乘以一三·七三六，即為該煤之有機硫份。

f. 有機硫質之分類及其鑑定——有機硫質約分為二種：一為膠性硫質 (Phenolic or resinous sulfur)，係溶解於石炭酸 (Carbolic acid or phenol) 之有機硫質。一為不溶解於石炭酸之有機硫質，名曰腐植硫質 (Humus Organic Sulphur)。其鑑定之方法如次：

盛一·三三六克之煤末於五十立公分之三角玻璃瓶 (Erlenmeyer Flask) 內，傾入以二十五立公分之熱石炭酸。瓶口塞以軟木 (Cork)，並通以長二尺許之玻璃管 (Glass Tubing)，以防石炭酸氣體之揮發。置此瓶於油鍋 (Oil Bath) 或電爐 (Electric Oven) 內，熱之至溫度約達百五十度，並在此溫度下經二十小時後用顧氏濾器 (Gooch Crucible) 乘熱濾之。洗以純酒，並使乾之。嗣將此乾燥物及石棉一併磨以二或三倍之愛氏混合劑。依法鑑定其硫份焉。是項硫份係不溶解於石炭酸之混合硫質之成分。故由全硫份減去是項硫份，始得溶解於石炭酸之膠性硫份。次由全有機硫份減去該膠性硫份，則得腐植硫份焉。

### (五) 分析之結果

I 無機硫份——分析之結果，第一步當屬各煤之全硫份。著者為避免重複起見，將此部並入表四。本節所列者，則為無機硫份之部。有機硫份則不及焉。

表三——各種無機硫質之成分，與由兩種不同之方法，所得之硫磺硫份及其比較。各煤之鐵量，亦一併列入。

試驗室號數	全無機硫份	硫酸硫份	硫磺硫份	硝酸鐵量	鹽酸鐵量	硫磺鐵份	硫磺硫份	相	差
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地質彙報

四〇	1.10	0.11	1.11	1.11	0.11	0.11	1.11	增0.01
三九	0.11	0.01	0.02	0.11	0.11	0.11	0.10	減0.01
三一	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.02
三〇	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二九	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二八	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二七	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二六	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二五	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二四	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二三	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二二	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二一	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二〇	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一九	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一八	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一七	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一六	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一五	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一四	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一三	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一二	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一一	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一〇	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
九	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
八	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
七	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
六	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
五	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
四	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
三	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
二	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01
一	0.11	0.02	0.04	0.12	0.12	0.12	0.10	增0.01

或謂有機硫質之一部，亦往往溶解淡硝酸。以試驗度之，不為無因。蓋上表所列之硫磺硫份由硝酸浸液所鑑定者，大抵高於該項硫份由各該煤之鐵量計算所得之數字。著者遂亦以後項數字為準確之硫磺硫份焉。

煤中之硫酸硫份，大抵甚少，前已道及。但證諸上表，似不盡然。此殆係某數種煤樣之出井時間較久所致。

II 全有機硫份——由兩種不同之方法所得之全有機硫份，稍有出入。茲列表四以比較之。並以各平均值為各該煤之全有機硫份之準確數字云。

表四——全有機硫份，包括比較及其平均值。

試驗室號數	全硫份	硫磺硫份	硫酸硫份	全有機硫份(間接)	全有機硫份(直接)	相 差	全有機硫份(平均)
三〇六	二·六	一·二	〇·五	一·五	一·四	增〇·〇一	一·四
三〇九	〇·空	〇·一〇	〇·〇三	〇·五	〇·五	減〇·〇三	〇·五
三一一	一·四	〇·四	〇·八	〇·五	〇·五	增〇·〇三	〇·四
三〇九	〇·空	〇·四	〇·六	〇·七	〇·六	減〇·〇一	〇·六
三〇三	〇·九	〇·三	〇·〇三	〇·五	〇·五	減〇·〇四	〇·五
三〇九	〇·四	〇·三	〇·〇六	〇·四	〇·五	增〇·〇一	〇·五
三〇九	〇·九	〇·〇三	〇·〇三	〇·四	〇·五	減〇·〇一	〇·五
三〇三	〇·七	〇·一四	〇·一三	〇·七	〇·六	增〇·〇一	〇·七
三〇九	一·五	〇·四	〇·一七	〇·八	〇·八	減〇·〇一	〇·八
三〇九	五·四	三·六	〇·五	一·五	一·六	減〇·〇四	一·五
三〇九	一·六	〇·六	〇·〇七	〇·三	〇·六	減〇·〇三	〇·六
三〇三	〇·七	〇·八	〇	〇·四	〇·四	增〇·〇三	〇·四
三〇九	〇·空	〇·〇一	〇	〇·四	〇·三	增〇·〇一	〇·四
三〇七	三·三	一·三	〇·三	一·六	一·五	增〇·〇三	一·六

六號

0.56

0.92

0

0.84

0.84

無增減

0.84

兩種全有機硫份，雖少有出入。然究未出乎可能的試驗之錯誤。故以各平均值為準確之數字。庶與理論之數字，更近似矣。

III 兩種有機硫質之分析：

表五——兩種有機硫質之成分。

試驗室號數	全 硫 份	石炭酸不溶硫質	膠 性 硫 質	全有機硫份(平均)	腐 植 硫 質
三〇六	二.六六	二.七三	0.14	1.89	1.75
三〇九	0.65	0.64	0.01	0.65	0.54
三一三	1.82	1.83	0.01	0.84	0.83
三一四	0.52	0.49	0.03	0.36	0.33
三一五	0.64	0.53	0.08	0.56	0.48
三一六	0.64	0.64	0.00	0.53	0.49
三一七	0.64	0.64	0.00	0.56	0.53
三一八	0.64	0.64	0.00	0.56	0.53
三一九	0.64	0.64	0.00	0.56	0.53
三二〇	0.64	0.64	0.00	0.56	0.53
三二一	0.64	0.64	0.00	0.56	0.53
三二二	0.64	0.64	0.00	0.56	0.53
三二三	0.64	0.64	0.00	0.56	0.53
三二四	0.64	0.64	0.00	0.56	0.53
三二五	0.64	0.64	0.00	0.56	0.53
三二六	0.64	0.64	0.00	0.56	0.53
三二七	0.64	0.64	0.00	0.56	0.53
三二八	0.64	0.64	0.00	0.56	0.53
三二九	0.64	0.64	0.00	0.56	0.53
三三〇	0.64	0.64	0.00	0.56	0.53

五二	0.5	0.7	0.8	0.6	2.6	0.6	0.5
五七	3.5	2.6	0.9	1.6	5.6	1.6	1.1
六	0.5	0.4	0.5	0.5	0.5	0.5	0.4

由上表可知有機硫質中之腐植硫質占絕對多量。

分析之總結：

表六—總結各項分析之結果。並比較各煤內諸硫份之和與各該煤之全硫份。

試驗室號數	硫磺硫份	硫酸硫份	腐植硫份	膠性硫份	諸硫份和	全硫份	相 差
三〇六	1.1	0.3	1.5	0.4	2.3	2.6	減0.01
三九	0.10	0.03	0.5	0.01	0.6	0.5	增0.03
三一	0.60	0.2	0.3	0.01	1.1	1.3	減0.01
三六	0.4	0.2	0.3	0.5	0.6	0.5	增0.01
三三	0.3	0.03	0.6	0.6	0.6	0.6	增0.03
三五	0.3	0.2	0.5	0.2	0.3	0.4	減0.01
三九	0.03	0.3	0.5	0.10	0.9	0.7	增0.01
三四	0.4	0.1	0.5	0.10	0.6	0.7	增0.01
三六	3.6	0.5	1.4	0.4	5.9	5.4	增0.01
三五	0.6	0.7	0.4	0.1	1.8	1.6	減0.01

地質彙報

五三	0.08	0	0.04	0.01	0.6	0.7	減0.01
五一	0.01	0	0.6	0.8	0.5	0.5	無增減
五七	1.5	0.3	1.1	0.4	3.3	3.3	減0.01
六五	0.08	0	0.4	0.8	0.5	0.5	無增減

總上分析結果，頗稱近似。此殆充分表現鮑氏及巴氏法之應用矣。

### (六) 結論

- I 沿用鮑氏及巴氏法所得之結果，頗稱精確。該法之詳細步驟，已一并列入本文。
- II 淡硝酸能溶解一部分有機硫質。故鐵量之鑑定極為重要。
- III 淡硝酸能溶解全部二硫化鐵，及其他溶解於淡鹽酸之鐵質。故由鐵量計算所得之硫磺份，較為準確。
- IV 全硫份中大抵以有機硫質之成分為最高。
- V 有機硫質內之膠性硫質，含量頗少。且少於腐植硫質。
- VI 硫酸硫質之含量應極低，惟以某數煤暴露於空氣中時間較久之故，以致其成分稍高。
- VII 半烟煤及低級烟煤浸蝕於濃硝酸之時間應久，次數應多。俾使全部有機物質得溶解於濃氫氧化銨水，以便鑑定。

### (七) 志疑

淡硝酸能溶解全部二硫化鐵，及一應鹽酸所能溶解之鐵質，而不能溶解矽酸鐵，此為事實。著者並假設華煤中之鐵質惟有二硫化鐵能溶解於硝酸，而不溶解於鹽酸，而有前項之結論焉。究於實際，是否如此，猶是疑問。蓋煤內或有與二硫化鐵同性質之鐵質：即溶解於硝酸而不溶解於鹽酸之時，則其由鐵量所計算之硫磺份，應高於實際之硫磺份矣。若然則前項結論，將無以自立矣。惟著者僅就試驗之結果，下該斷語，初未顧及是項可能之事實。且試驗所及，亦未發現類似該項之事實。其所可疑者則



有三一九，四四八，及五九一，等三煤樣。因該三煤之由硝酸侵液所得之硫磺硫份，小於由該煤鐵量所計算之該項硫份。惟以各該煤之硫磺硫份，相差無幾（百分之〇・〇一一〇・〇三）。或屬可能之試驗錯誤，抑確有與二硫化鐵同性質之鐵質存在，未審孰是，茲誌以存疑。

#### （八）鳴謝

著者甚荷本所技師金開英先生之熱心指導與匡正，特此鳴感。又洪會荃女士供給本篇以煤之實用分析表，亦一併申謝。參攷書目已列入英文篇，不另述。



# 測定煤內硫質之新法

楊珠瀚

## (一)緒言

愛氏法 (Eschka Method) 自一八七〇年以來，迄數十年尚無較完善方法，其間雖有彈瓶洗滌法 (Bomb Washing Method) 及過氧化鈉法 (Sodium Peroxide Method)，各有優點，然究屬不無遺憾。是以前者迄保持其優越之地位，進而為公認之標準方法焉。惟該法需費較昂。晚近學者致力於此研究者頗不乏人，就中以伊氏 (Ivison) 之方法似較便利而可靠。其法即以石灰與碳酸鈉之混合物，代替愛氏混合劑。著者以此施諸華煤之分析，頗覺有一困難，即用伊氏混合物所得煤之熔融物 (Fused mass) 頗難粉碎。著者因思及該熔融物之所以不易粉碎者，純係碳酸鈉之故，并思有以代之。

硝酸鈉之為物熔點甚低，且易熱解而發出氧素。如以此種物質代替碳酸鈉，其結果將大見進益，蓋此氧素逕可應用於煤內硫質之氧化，於理既然，應用結果亦稱足符此旨。

本混合物之配合，以三份之氫氧化鈣(熟石灰)與一份之硝酸鈉，研碎攪勻備用。

## (二)分析之手續

- (1) 本鑑定之手續大約與拙著華煤中硫質種類之分析文內全硫份之鑑定相同。
- (2) 著者於溶融煤質時係用細高式磁杯 (High-form Porcelain Crucible)，其體積約三十立公分 (Cubic Centimeter, C.C.)。
- (3) 溴水之加入在本方法為可免之步驟，蓋硝酸鈉之存在於先，已足使全部硫質變為硫酸基 (Sulphate Radical) 而有餘，雖然，為萬全計，究以加入少許為是。
- (4) 普通藥品中往往含有少許某種硫質，鑑定此項硫份之於分析工作乃為必要之手續，茲篇當亦不能例外。
- (5) 煤內之灰份不得與硫份同時在同一電爐內鑑定之，蓋煤在燃燒時往往有氧化硫氣體發出。後者將有被所用之混合物吸收

之虞。

(三)分析之結果

試驗室號數	愛氏法之結果(百分率)	本方法之結果(百分率)	相 差(百分率)
15	一·三三三	一·二六六	減〇·〇七
14	三·七三三	三·七三三	〇
13	三·三三一	三·三二二	減〇·〇九
12	〇·七二二	〇·七二二	〇
11	〇·六二二	〇·六四四	增〇·〇二
10	二·六六六	二·六二二	減〇·〇四
9	三·九四四	三·八六六	減〇·〇八
8	〇·六〇〇	〇·六〇〇	〇
7	〇·六三三	〇·六二二	減〇·〇一
6	三·三三九	三·三三〇	減〇·〇九
5	七·四一	七·三三〇	減〇·一
4	六·〇五	五·八七七	減〇·一八
3	〇·一五	〇·一七七	增〇·〇二
2	〇·四一	〇·四一	〇
1	〇·七二	〇·七七	增〇·〇五

24	23	22	21	20	19	18	17	16
○·五三	一·一二	○·四七	○·四六	二·一八	○·八六	○·五九	五·二八	三·二九
○·五六	一·一四	○·四八	○·四八	二·〇八	○·八五	○·五九	五·二六	三·二三
增○·〇三	增○·〇二	增○·〇一	增○·〇二	減○·一〇	減○·〇一	○	減○·〇二	減○·〇六

#### (四) 結論

(1) 本方法以分析之結果言之與愛氏法不相伯仲，惟於硫質稍高之煤樣結果視愛氏法為低，最大差數為百分之六之六之硫份中差百分之〇·一八(錯差約百分之三)，謂為試驗之錯誤當亦無不可。

(2) 本方法之主要優點乃為需價低廉，氧化鎂每磅售金元三元五角，氫氧化鈣則需一元三角(碳酸鈉與硝酸鈉幾屬於相同之價格)，相差不為不鉅矣。

(3) 本方法在某種臆測之下，視愛氏法為劣。

(a) 本混合物之體積經熔融後不似愛氏混合劑之高度的收縮，而使洗滌費時。

(b) 未經熾熱之愛氏混合劑體質鬆散，其體積殆視本混合物而倍之。其於氣體之吸收也當有加倍效率。著者因是之故，

舍較廉之生石灰，而樂於用熟石灰也。



# 中國烟煤之溶劑試驗

賓 果

## (一) 緒言

烟煤之化學成分甚不易知，蓋實用分析僅知揮發物固定炭若干，而揮發份實僅一籠統名詞，其中所包何種成分仍未知也。如作元素分析，則又將煤質破壞過甚，只知其元素成分，而不能得原含之化學組合。自馬錫爾氏發現煤中之有機質能以溶劑取出後，學者迭加試驗，皆企以此法得知煤之化學成分。然研究之結果甚多，演繹之理論亦衆，而煤之化學組成固仍曖昧不明也。

溶劑之可用於此試驗者甚多，其較優者首推吡啶 (Pyridine) (化學專名皆遵用教育部公布化學命名原則) 最初爲彭特生氏所採用，據哈格氏稱吡啶溶煤力之所以強者，以其對煤中之複化合物有相當化學分解作用，非僅單純之物理作用已也。衛力及柯賴氏更將吡啶所溶者以三氯甲烷 (Chloroform) 再分別之，並將此二溶劑所分開之部分各列如左：

甲化合物——煤中部分之不能溶於吡啶者

乙化合物——煤中部分之溶於吡啶而不溶於三氯甲烷者

丙化合物——煤中部分之溶於二種溶劑者，爲明瞭此分開手續起見列表如下：

煤 + 吡啶	溶解者 + 三氯甲烷
	不溶者——甲化合物
煤 + 三氯甲烷	溶解者——丙化合物
	不溶者——乙化合物

甲乙兩種化合物爲同一之物質，其由來多自植物。丙化合物則類樹脂。論者皆謂煤之能適於煉焦與否，均視丙化合物之多少爲斷，以其富有膠結能力故也。

吾國烟煤儲藏甚豐，以產地之不同，成分迥異，其煉焦之可能性亦復懸殊，故在大規模應用之先，煤樣之測驗至爲重要。研

究是否以溶劑方法可預斷烟煤之焦性，乃本試驗之目的。

(二)煤樣

所擇煤樣均採自重要礦場，其質皆為烟煤凡十六種。其地質年代，減潮減灰之實用分析，列表如下。

試驗室號數	產地	公司	地質時代	揮發物	固定炭
三二一	河北磁縣	怡立	二疊石炭紀	二二·二八	七七·七二
三一九	河北磁縣	怡立	全上	二二·七二	七七·二八
三一〇	山東博山	博東	全上	二五·六七	七四·六三
三〇九	山東博山	博東	全上	二四·〇〇	七六·〇〇
三六五	河南六河溝	井陘	全上	二八·一五	七一·八五
三六二	河北井陘	井陘	全上	二六·七二	七三·二八
三七四	河北灤縣	開灤	全上	三五·九六	六四·〇四
三七三	河北灤縣	開灤	全上	三五·七六	六四·二四
三六九	山東峰縣	中興	全上	三四·二一	六五·七九
五八七	安徽舜耕山	大通	全上	三八·七五	六一·二五
五九一	湖南湘潭	有利	二疊紀	二三·六九	七六·三一
五九七	浙江長興	長興	全上	四二·三九	五七·六一
四四八	安徽宣城	全上	全上	四一·六六	五八·三四
六五五	江西萍鄉	萍鄉	侏羅紀	三六·四二	六三·五八



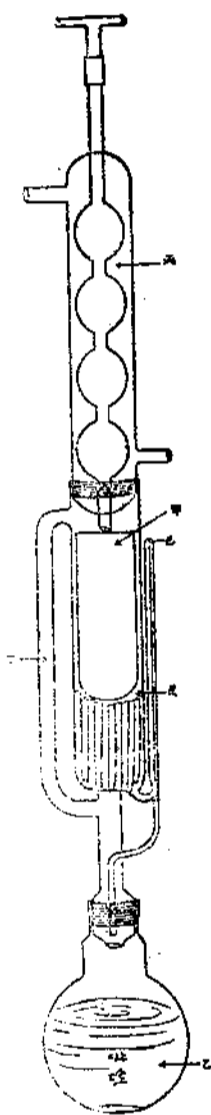
三四九	察哈爾宣化	厚	全	上	四二·六八	五七·三二
五二二	山西大同		全	上	三八·〇一	六一·九九

(三) 各煤之焦性

- 三二一及三一九係同自一礦而不同煤層，二者皆可成粘結之半焦，但三一九微縮而三二一稍脹。
- 三〇九及三一〇此煤已用於土法及新式煉焦，三〇九之半焦甚脹，有光澤，堅硬並多氣孔，三一〇之半焦稍脹亦堅硬。
- 三六五近數年來已用之於煉焦，可為鍊鐵用，其半焦堅硬，有光澤，且膨脹。
- 三六二加熱時收縮成堅實之半焦，此煤用之於井陘礦局之副產煉焦爐，其最大之產額，每日可至百一十噸。
- 三七三及三七四其半焦稍脹，堅硬而有光澤，此煤已用於新式之蜂巢式煉焦爐。
- 三六九其半焦甚脹，多孔而易碎，當地用此煤煉焦，月產約三千二百噸。
- 五八七其半焦堅實而微縮，通常以為不宜煉焦。
- 四四八其半焦甚脹，多孔易碎，惟含硫甚多，是其缺點。
- 六五五其半焦有粘性稍硬，其焦炭已大量用於冶金。
- 五二二因其富於絲炭故不宜煉焦，其半焦稍具粘性而粗鬆，極易碎為粉末。
- 三四九不能煉焦，毫無粘性，但富於揮發物。

(四) 實驗方法

本試驗採用美國礦務局所用方法，茲略述如下。以一公分過六十孔篩已乾煤末與四至五倍體積之淨砂混合，置於鋁土瓷管(Alundum Thimble)中，於蘇克施器(Soxhlet Extractor)中，以百二十五公分之吡啶提出之。蘇氏器之構造如圖所示。



甲，即鉛土瓷管，有微孔，溶劑可滲透。乙為燒瓶中置吡啶。丙為冷凝器，上接丁字形管。管之兩端一接抽氣機，一接蓄氣器，將蘇氏器抽空，貯以氮氣，於瓶底加熱，吡啶蒸氣沿丁管上升至冷凝管結而下降於瓷管中。煤中有機質之一部，漸溶解，自管中滲出。迨戊筒中溶液表面過「已」管時，即因虹吸作用溶液盡流下瓶中。溶劑再蒸發至瓷管，再落下，如是循環，直至下降溶液無色時為止，調節熱度，使每十分鐘循環一次。試驗終始約需四十八小時。將溶液濾入一已知重量一百五十公分之燒瓶中，蒸餾吡啶，使濃至溶液將乾涸時，逐次加十五公分之二甲烷苯 (Xylene)，蒸發直至吡啶惡臭驅盡為止。將燒瓶置一〇五至一一〇度之真空乾燥器中使乾。冷卻後衡其重。乙丙兩種化合物之總量即燒瓶前後之差。以三氣甲烷代吡啶，依同一方法可使乙丙兩種化合物分開，而得其重。惟蒸發溶液時可不用二甲烷苯而已。

(五) 結果

依減灰煤計算，所得結果如下。

煤	吡啶吸收者	甲 $\alpha$	乙 $\beta$	丙 $\gamma$
三二一	二·七四	九七·二六	〇·四六	二·二八
三一九	三·九五	九六·〇五	一·二九	二·六六
三一〇	六·八二	九三·一八	二·〇三	四·七九
三〇九	七·二四	九二·七六	〇·六六	六·五八

三六五	六·〇七	九三·九三	二·三九	三·六八
三六二	六·三七	九三·六三	一·七四	四·六三
三七四	二九·四一	七〇·五九	一八·〇九	一一·三三
三七三	三二·七二	六七·二八	一六·九五	一五·七七
三六九	三二·七五	六七·二五	一六·三三	一六·四二
五八七	一一·一二	八八·八八	四·八五	六·二七
五九一	七·七三	九二·二七	二·九七	四·七六
五九七	一八·七五	八一·二五	八·六三	一〇·一二
四四八	一九·二一	八〇·七九	七·九三	一一·二八
六五五	二二·四四	七六·五六	一三·五二	九·九二
三四九	一四·五一	八八·四九	六·〇七	八·四四
五二三	一九·五二	八〇·四八	一〇·三六	九·一六

(六) 討論

爲討論時簡易起見，茲將下表列入。

煤	時 代	記號	加水燃率	$\gamma$	產油量	膨脹係數
三二一	二疊石炭紀	Bh	三·四四	二·二八	五·七三	一·〇六
三一九	二疊石炭紀	Bh	三·三七	二·六六	四·九七	—
三一〇	二疊石炭紀	Bm	二·八八	四·七九	五·七〇	一·〇四

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三〇九	二疊石炭紀	Bh	三·一六	六·五八	五·〇五	一·四〇
三六五	二疊石炭紀	Bm	二·五〇	三·六八	五·九二	一·〇四
三六二	二疊石炭紀	Bm	二·七二	四·六三	六·六五	〇·九〇
三七四	二疊石炭紀	Bm	一·七三	一·三二	一〇·五〇	一·一四
三七三	二疊石炭紀	Bm	一·七八	一五·七七	九·七六	一·九六
三六九	二疊石炭紀	Bm	一·九〇	一六·四二	八·〇五	二·五六
五八七	二疊石炭紀	Bl	一·五一	六·二七	一二·一〇	〇·九四
五九一	二疊紀	Bh	三·一二	四·七六	四·六五	一·〇〇
五九七	二疊紀	Bl	一·三四	一〇·一二	七·五九	二·七二
四四八	二疊紀	Bl	一·三九	一一·二八	八·三七	二·六四
六五五	侏羅紀	Bl	一·六九	九·九二	九·一五	一·〇〇
三四九	侏羅紀	Bl	一·二七	八·四四	一〇·五〇	一·〇〇
五二三	侏羅紀	Bl	一·五五	九·一六	一一·〇五	一·〇〇

上表中加水燃率係據金開英洪曾荃著各省煤質分析。產油量係據蕭之謙低溫蒸餾試驗。

(七) 加水燃率與丙化合物之關係

固定炭與水份及揮發物之和之比名曰加水燃率，蓋此可以表示煤之碳化程度，即碳化高者其燃率亦增高，今將丙化合物及吡啶所溶者，與加水燃率所作之兩曲綫列後。(見英文籍中)

曲綫雖如犬齒交錯，毫無一定規則，但細考之則凡在加水燃率二·五以上者，丙部份之差別甚小。在二·五以下者，則參差

不齊。粘結而膨脹者其丙成分多不粘結，及稍粘結者其丙成份稀少。據實驗所得五二三，五八七，及三四九各號煤其焦性甚小，四四八，五九七及五九一各號煤性不明，其餘皆為優良之煉焦煤，其出產之焦皆已銷用於市場。由此言之，丙化合物對於烟煤之粘性甚為重要，再於丙化合物曲綫上最可注意之點，即位於曲綫上最高點之煤，當加熱時其膨脹甚大。例如五九七，四四八，三七三，三六九及三〇九，各號。反之，煤之位於曲綫較低位置者，則不甚脹，或不服，或竟於加熱時而起收縮。此或為諸煤之本性，亦未可知。

#### (八)地質年代與丙化合物之關係

如不計煤之碳化程度或加水燃率，煤之丙化合物似與其粘性無關，蓋不能煉焦者如三四九號含丙化合物百分之八·四四，而焦性甚佳者如三二一號僅含百分之二·二八。然將各煤按地質時代分列，而再視其粘結力與丙化合物之關係，則似頗有相當之規則。

侏羅紀煤中有良焦性，並已用於煉焦之六五五號，含有百分之九·九二之丙化合物，焦性甚劣之五二三號則含百分之九·一六，而不能煉焦之三四九號僅含百分之八·四四。二疊紀之煤關係亦然：五九七號及四四八號其半焦膨脹甚大，含丙化合物百分之一〇·一二及二·二八，半焦不脹之五九一號含百分之四·七六，二疊石炭紀中三六九號含百分之一六·四二，其半焦膨脹亦甚，其次三七三號三七四號含百分之一五·七七及一一·三二，其餘除五八七號含百分之六·二七外，當加熱煉焦時皆微脹且其丙化合物之百分數皆較三七四及三六九為小

#### (九)煤之炭化程度對於丙化合物之影響

何以侏羅紀之煤如三四九號及五二三號含丙化合物多而焦性劣，而二疊石炭紀者如三一〇號及三二一號含丙化合物少而焦性良。不同之煤其所含之丙化合物似亦不同，丙化合物既已證明類似樹脂並斷為古代植物所遺留之樹脂復化而成者，按諸定則，復化作用與時間之久暫溫度之高低以及壓力之大小有密切之關係，而復化物之分子量較原化合物者為大，因是其熔點沸點均較高。

丙化合物之變遷亦復如是。年代愈長，炭化愈久，溫度愈高，其複化程度亦愈深，是以其熔點沸點亦因之愈高也。

煉焦之時煤中之丙化合物分解為簡單之化合物，如煤氣，油類，瀝青之屬，而碳分較高之化合物，則膠結煤末而成焦。溫度愈高則後者之產生亦多，分子量較小之丙化合物易蒸發，且未至高溫即行逸出，故不易分解。反之，分子量較大者，蒸發較難，在低溫不易出，直至高溫遂分解。此次試驗結果，頗為明晰，侏羅紀煤含丙化合物多，並無補於焦性，僅增油之產量。二疊石炭紀之煤如三六九，三七三等各號所含丙化合物亦多，而油量頗少，是知其丙化合物大部用於膠結也。

總之，煤之焦性不能僅恃其丙化合物之多寡，而須視此化合物之本性，及其分解後之物質為定。如本試驗所示年代較近之煤，雖富有丙化合物而其焦性殊劣。時代較遠之煤，其丙化合物較少而焦性甚佳。故別擇烟煤以煉焦者，不可僅測其丙化合物之多寡，同時於地質年代亦宜兼注意及之。

### (十) 綱要

本試驗以溶劑方法測定各地烟煤十六種之焦性，其結果如下(一)僅以丙化合物之含量而預定，煤之焦性絕少把握。(二)選擇煉焦烟煤時，除丙化合物外，其來源，時代以及炭化程度等均應注意，始可得相當之標準。

參攷書見英文篇中。

# 平陽礬石之加熱試驗

金開英 蕭之謙

## (一)引言

礬石之蘊藏於吾國東南海岸者在三百年前已經發現。此全部儲藏及其多寡之程度已為葉良輔君在其調查平陽地質報告中詳細載明。此礦之唯一用途，至今仍用於製造明礬工業。所用之士法恆先將礬石烘炙，再加水使明礬溶解而滲出。此法所得成分僅佔純礬石百分之二十五。而通常製造之成分尙小於此數。故為增加明礬生產效率及增加礬石之豐富效用計，作此煨燒試驗。

## (二)以往方法

十三世紀時意大利多爾福 (Tolfa) 地方已有由礬石提取鉀明礬之方法，在奧大利亞之布拉底拉 (Bullah Delah) 將礬石在反射爐中燃燒，再加弱硫酸使起反應。郭歐 (Guyot) 氏謂將礬石加熱至八百度，三小時後加入硫酸及硫酸鉀即可得原礬石重二·三倍之明礬。而蘇瓦氏 (Schwartz) 則提示以五百度為煨燒熱度之最佳者。

其直接由礬石中得硫酸鉀為衛格門 (Waggonman) 氏所創。大戰時，美國工商界曾以此法於由他 (Utah) 省之馬斯維爾 (Maysville) 一帶提製硫酸鉀，該處為美國儲量最富之地，此礦物加熱至千度可得礬土及水可溶之硫酸鉀。

愛特活氏 (Edwards) 等曾發表多種製純礬土之方法，其大部論及初步之煨燒以增加礬土在酸中之溶解率。其溫度分割為三級，五百至七百五十，七百五十至一千，一千至一千六百度。由初級溫度可得能溶於酸之硫酸鹽，由次級溫度可得三氧化二鋁及硫酸鉀，最後級溫度可得礬土及硫酸鉀之蒸氣或鉍酸鉀。後更經范開 (Finn) 等用 X 光綫分光法證明此種分解，並說明當溫度自五百度至六百度時，礬石變成無水極微之結晶，此物待溫度由七百至八百時再分解為鋼玉及硫酸鉀，溫度更昇自千二百度至千四百度時氧化鉀與三氧化二鋁化合成  $K_2O \cdot Al_2O_3$ 。

又歐勃 (Ogburn) 及斯的爾 (Stern) 二人以為當礬石熱分解時共分為兩步驟，即在四百六十度時結晶水游離，而八百度時硫

酸鉛完全分解為礬土，而此溫度與硫酸鉀則毫無影響仍保持其為  $K_2SO_4$  之原狀。（參攷書目見英文）

(三) 礬石標本之化學成分

所用標本為浙江平陽之細花，生子，大花及虎斑四種。細花之標本中因其所含砂石之百分率極少，故用以作試驗之材料。下表所示為該礦物之化學成分。

第一表 礬石之化學分析

	百分率
水 - (粘附之水氣)	〇〇・一四
水 + (結晶水)	一〇・〇〇
氧化矽	一八・〇〇
氧化鋁	三三・六五
氧化鐵	〇〇・五七
氧化鈣	〇〇・二二
氧化鉀	八・六四
氧化鈉	〇〇・三六
三氧化硫	二八・八六
總計	一〇〇・四四

此標本中算出含有百分七四・七之礬石（化學式為  $K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$ ），二・八四之高嶺土，一六・六八單體之氧化矽，四・三九之礬土及如上表所示之其他雜質。

(四) 溫度對於礬石分解之影響



今述礬石在溫度不同時之分解量，以三克至五克之標本（磨細使通過四十孔之篩）稱準後置入砂綫石之床，再安放於插入管狀爐中之砂質管中，此中溫度用一電溫計節制之。每種新礬石均於溫度百度時放入。每過一定時間，將砂綫石之床取出並衡其重，如是數次迄熱量增加而其重量仍不變時為止。並由分析始知其中三氧化硫之含量及氧化鋁在硫酸中之溶度。其結果如下表所示。

第二表 各溫度中礬石之分解

溫度 (攝氏)	總失重 (百分率)	三氧化硫之失重 (百分率)	水分之失重 (百分率)	三氧化二鋁對於百分之十 硫酸之溶解度 (百分率)	加熱時間 (小時)
不加熱	○	○	○	七·〇〇	○
一〇〇	○·一一三	○	○·一一三	—	一〇·七五
二〇〇	○·二一五	○	○·二一五	七·二〇	一〇·二五
三〇〇	○·二四八	○	○·二四八	—	八·〇〇
四〇〇	○·二七一	○	○·二七一	七·五一	一二·五〇
四五〇	二·五七	○	二·五七	—	二五·二五
四五〇	五·一三	○	五·一三	—	六〇·〇〇
五〇〇	一〇·三二	○·三三	九·九九	九七·二五	二四·〇〇
六〇〇	一一·五三	一·五三	一〇·〇〇	八九·五〇	二六·五〇
七〇〇	二八·一〇	—	—	—	二二·五〇
七〇〇	二九·二〇	一九·二五	一〇·〇五	八七·〇〇	四一·五〇
八〇〇	三一·九八	二二·〇〇	九·九八	七三·六〇	二四·〇〇
九〇〇	三二·八〇	二二·八一	九·九九	六八·八〇	二四·五〇

如此礬石分解之兩種顯明之步驟可以洞悉。四百度時僅失其粘附晶形之水氣而無變於其本質。結晶水之游離於四百五十度時開始而於五百度則急速散盡（如曲綫第一陡起部位所示）。水之完全游離與三氧化二鋁在酸之溶解度忽然增加，同時並進。此或為無水化明礬結晶之生成如范開氏所言。此亦被認為製造明礬最適宜之條件。熱至七百度時，硫酸鋁大部份分解，因而有多量三氧化硫之發出。其時鋼玉即與硫酸鉀分散而成水不溶之物，致使礬石之溶解度降低。

(五) 加熱後明礬及硫酸鉀之提取

欲證明上述之結果，必須作一規模稍大之試驗，於兩種溫度中提取硫酸鉀及明礬。故實際上宜以八百度代替七百度。因如此則硫酸鋁之分解較為完全，加熱時間可縮短，即燃料可以節省。每次試驗以二百克之同樣標本置於瓷皿，使之受熱於電爐中至二十四小時（此為每種及應完成時間之平均值）。再從此種加熱標本提取各種物質及其餘剩之氧化鋁，其結果如下表。

第三表 加熱後提取之結果

溫 度	五〇〇	八〇〇
加熱後失重	二〇.〇〇(百分之十)	六一.八〇(百分之三〇.九)
所用溶劑	水	水
提得之明礬	三〇.二克	八六.〇克
加入硫酸鉀後所增加之明礬	—	四〇.〇(不純之氧化鋁百分率為七.五五)
不加硫酸鉀理論上應得之明礬	一七.一克	—
提得明礬之百分率	一七.六五	五〇.三〇
明礬之熔點(攝氏表)	九〇.七—九一.五	九〇.五—九一.二
理論上之熔點	九二度(攝氏表)	—

提得之硫酸鉀

硫酸鉀之純性

理論上應得之硫酸鉀  
(由氧化鉀含量計算)

提得硫酸鉀之百分率

所餘殘渣

殘渣中氧化鋁之百分率

殘渣中氧化鋁之重

產品中氧化鋁之重

總量

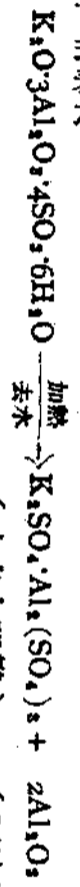
原礦物中氧化鋁之重

原礦中氧化鋁與硫酸鋁中總量之差

由此產出之明礬成分甚純可由其結晶之構造及熔點之試驗證明。其中少量雜質係用自來水提煉之故。硫酸鉀顯然猶含少量明礬即尚未因煨燒而分解之明礬。

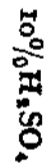
(六) 試驗結果之討論

由礬石得明礬之作用可由下式表之

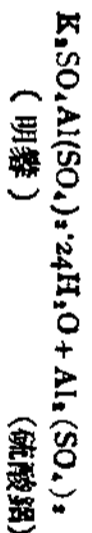


(去水之明礬)

(可溶於酸之礬土)



百分九十七  
濃度按



(明礬)

(硫酸鋁)

原來帶水礬石及去水礬石之性質，完全迥異，原因為何則尚不知。或係水之分子吸引去水明礬及鋁土化成爲不溶解物質而僅以灼熱始得分解之，此去水明礬之難溶於水卽爲土法及本試驗中產量甚少之主要原因。故應用酸類爲溶劑以增其溶度實爲重要。設能研究酸性強度及去水明礬溶度之關係，則其產量或可望增至百分之五〇·三以上。液中之硫酸鋁固可因加入硫酸鉀而得多量明礬，然未能完全化爲明礬，是以液中之鋁應若何悉數取出或化爲明礬亦宜注意。此或在硫酸鉀及硫酸鋁濃度之物理變化有關於明礬結晶之條件。

苟非利用三氧化硫及所遺之三氧化鋁則直接加熱至八百度以製硫酸鉀之法似欠經濟。況試料中二氧化矽百分率甚高，故應先提取純潔明礬而再煨燒之以得硫酸鉀及三氧化二鋁，此種方法可得純潔之明礬於先，更能得純粹之成品於後。

中央研究院地質研究所葉良輔先生供給著者以多種明礬石標本特此誌謝。

# 綏遠白雲鄂博鐵鑛報告

丁道衡

## (一)緒言

民國十六年夏季，著者隨西北科學考查團前往西北考查，取道蒙古草地，六月行抵綏遠固陽縣屬之阿穆塞。七月二日北隊由阿穆塞啓程，向東北行三十里，住於白雲布拉克。此地盡爲花崗岩之露頭，地勢甚爲平坦，略有丘陵起伏而已；惟北部山嶺名白雲鄂博，向東西蜿蜒，頗爲壯觀。三日晨著者負袋趨往，甫至山麓，卽見有鐵鑛鑛砂沿溝處散佈甚多，愈近鑛砂愈富，仰視山巔，巍然矗立，露出處，黑斑燦然，知爲鑛床所在，至山腰則鑛石層累迭出，愈上鑛質愈純，登高俯瞰，則南坡半壁皆爲鑛區。隨由詹君蕃助測成二萬分之一地形圖一幅，著者卽用此圖將鑛區內地質情形詳加調查，并採取各部鑛石以供室內之研究，今研究之結果，於其鑛床之分佈成因，鑛量及成分，各得其大概。茲爲敘述便利起見，分爲位置及交通，地層，地形及構造，鑛產三章分論如下：

## (二)位置及交通

白雲鄂博，蒙人亦名白雲博格都，譯意爲富神山，但山以鄂博著名，故蒙人稱此山皆曰白雲鄂博。此山在貝勒地內，屬札薩克親王蒙地，極西與茂明安旗交界，前爲綏遠庫倫交通必經之大道，今因外蒙獨立，此路已絕行人；大致言之，在綏遠西北約四百里之地，由綏遠啓程，經武川，察罕齊老圖，貝勒廟，勝金圖，朶昆而至白雲鄂博，馬行五天可達，現時綏貝汽車路已建築成功，全長約三百里，由綏遠開車，只須五六小時卽可達到貝勒廟，廟與鄂博之間約百里，道路平坦，車馬俱能通行，馬行半日可達。又該地距包頭約三百里，道路較爲不平，交通方面，全恃牲口，由包頭啓程，經五分子，羅博墩，阿穆塞，而到鄂博，約需五六日，附近無蒙人居住，只有王爺府所派蒙兵一排駐紮於此，以資守望而已。但二十里外則爲蒙古牧場，牲畜甚多。蒙人對於此山，極爲迷信，每年殺牲以祭，藉之乞福，山頂用鑛石堆積成包，以作神靈寄託之所，卽漢人亦多前往祭祀。又按此地地參謀

部圖上，似爲哈喇托落海，哈喇蒙意爲黑，托羅海意爲山頭，合之爲黑山頭，似即指此。

### (三)地層

元古界 白雲鄂博有元古界之地層露出爲石英岩砂質灰岩及板岩頁岩所組成，石英岩分佈於東坂谷內，大部爲砂土所蓋，似與石灰岩成不整一之狀況，因地層錯動甚烈，不易考定，砂質石灰岩則分佈甚廣，此地山嶺皆爲其所造成，向北延展尤遠，走向大致作東南西北，傾斜則北面較平南面頗峻。因附近花崗岩及閃長岩先後侵入之結果，變質甚深，而閃長岩之影響在本區尤爲重大。就岩石變質狀態及所生礦物而論，大部當係受閃長岩岩漿中所含氣體及溶液噴出之影響而發生，鐵礦之成功，亦基於此。此層厚度因褶皺過烈及殘破之關係，頗難斷定，但就地形觀之，至少可達五六百公尺，其時代就地位及岩質而論，似與中亞調查柏克及莫禮氏在蒙古所調查之五台系相當，但就砂質石灰岩厚度觀察，又與南口系相當，其精確年代尙須待較多事實之證明，方能決定。板岩頁岩則分佈於南階段，與灰岩作斷層接觸，地層褶皺甚烈，走向大致作西南東北，傾斜甚大，因受閃長岩之侵入，故變質甚深，板岩色灰黑，質甚細密，在顯微鏡下觀察，其片理甚爲清楚，且含蛋白石之細粒及炭質等物，石英細脈橫貫其間，有時亦含少許輝鐵礦。頁岩則多變爲片岩，其時代頗難鑑定，唯以山南三十里阿穆塞地層次序相比較，仍應屬於此紀，因在該地同一板岩頁岩層整合的在砂質灰岩之上也。

第四紀地層 此處除第四紀沖積層外，未見有中生代及第三紀岩層。第四紀則有黃土沙土及礫石等，分佈皆在山谷間，就地形而論，沉積并不甚厚，此處井水只深三四米突，似可爲一旁証。

閃長岩 閃長岩限於白雲鄂博之南坡，呈東西向之岩脈寬約二百米突，向西北東南伸延甚遠，侵入於花崗岩及板岩中，與砂質石灰岩之關係如何尙未發現。其發生時代，因附近較新地層皆不存在，故只知其元古界之後。但其分布甚廣，白雲鄂博東西各百里之處，皆有其踪跡，唯寬度大減，不過十米突而已。

### (四)地形及構造

包頭以北地形，大致言之，在郎山以北白雲山以南因撓屈作用成爲高地及盆地之地形，白雲鄂博適在高地帶中，故水系因之而異，山南則往南流，山北則往北流，北部之水如烏蘭布拉克，察罕托羅海，察罕齊老圖，皆向東北流，南部之水量較少，多爲溪澗，向東南或西南流。高山之頂形成一侵蝕平面，爲經撓屈後受侵蝕者，其時代似與蒙古侵蝕平面相當（註一）。山之南部爲一岩石階段，與高山相差約一百米突，其下爲內溝，澗溪流於其上，但以近日河床升高，水多入地，故非雨後，溝中無水，然掘地三四米突，即可見水，潛水面離地面固甚近。

其構造可分爲摺皺及斷層二部述之如下：

**摺皺** 白雲鄂博地層之摺皺，頗爲強烈，大致言之，摺軸作西北東南之方向，白雲鄂博適在一大外斜層之中心，其兩翼又作若干個摺皺，南翼似因火成岩所衝斷，而被消失，北翼則波行而前，延展甚遠，由山北望，視線所及，皆爲同一地層。地層則北部較平，愈南傾斜愈大，有近直立者，又如阿穆塞貝勒廟等處皆有同一現象，似表示摺皺之橫推力大部由南而北，此與大青山郎山烏拉山之摺皺方向完全一致（註二），亦可証其壓力之方向至白雲鄂博等地尙未變也。

**斷層** 在此區內，局部之斷層雖多，但與地形有重要關係者唯有二（一）在大外斜層之南翼，適居於高山與階段之間，作西北東南走向，以致變質石灰岩及鐵礦之一部與較新之板岩接觸，就地形及地層次序而論，則仰側居斷綫之北，適爲鄂博之部分，此斷層似向東西延展甚廣，西部因時間關係，未得沿綫勘察，其詳情不得而知；東部之斷層至五十里之處，仰側邊變在斷綫之南，似由於旋轉斷層之結果。（二）在山之北部溝內，大部爲黃土所蓋，但就地形地層言之，似有一斷層發生，高山與北低梁之間爲寬大之內溝，中有乾澗之河流，沿溝處且有若干石英岩脈之露頭，似皆由於斷層所致之結果，若此推想不謬，則白雲山應爲一地壘所成。斷層之時代，因其切斷鐵礦鑛床，而此鐵礦之發生，係由於閃長岩侵入之結果，其與閃長岩同時明甚，斷層則當在其後矣。此地撓屈之發生，就盆地內之沉積而論應在漸新紀以後，而因撓屈之作用，地層往往發生斷層，則此地斷層或即與其同時歟？

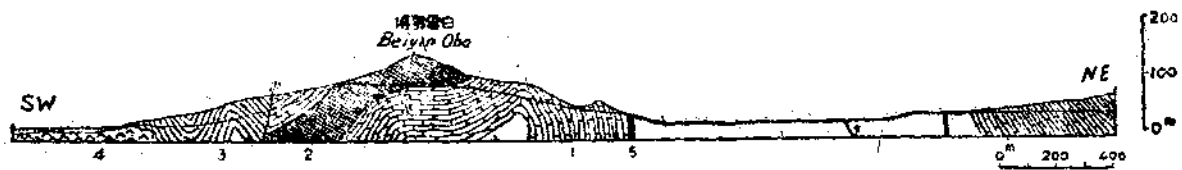


Fig. 1. Section (AB) across the Beiyin Obo 第一圖 經過白雲鄂博 AB 之剖面圖

- |                           |                |                   |       |
|---------------------------|----------------|-------------------|-------|
| 岩灰石質變                     | 鐵              | 鐵                 | 岩頁及岩板 |
| 1 Metamorphosed limestone | 2 Iron Deposit | 3 Slate and Shale |       |
| 岩長閃                       | 脈英石            |                   |       |
| 4 Diorite                 | 5 Quartz-Vein  |                   |       |

地質彙報

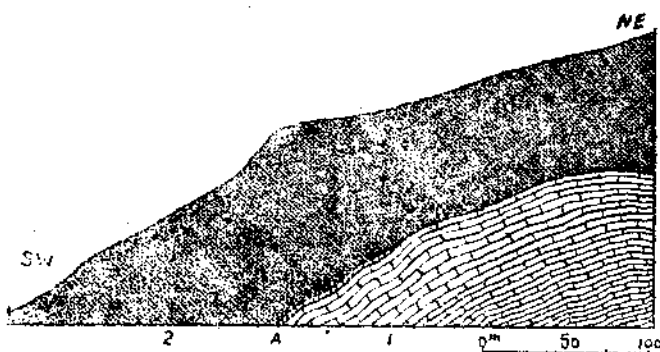


Fig. 2. Section showing the relationship between Iron Deposit and the Metamorphosed Limestone with a Vein of Epidote (A) (on the NW side of the mountain)

第二圖 鄂博山西 北面露出 之剖面表 示鐵礦與 變質石灰 岩之間有 綠簾石一 層

本區鐵礦以赤鐵礦及輝鐵礦為主要礦物，磁鐵礦及褐鐵礦則散見於石灰岩及石英岩中，似不甚重要，主要礦床位在白雲鄂博之頂部，即大外斜層之南翼，礦床起自北部蠟丘之中部，層疊而上，至山頂約五十公尺，向南坡而下，地層亦漸變峻斜，有時近於直立，由四十度至七十度最為普通，大致言之，佔全山頂及南坡之一部，其礦床似順南翼而插入地中，唯其深入若干，則非加鑽探之後，不能得知，北翼似因斷層關係向北下落，有無鐵礦之存在，因未親往調查，不敢斷定，唯由山頂遙望，地層中時露黑色之層，或即礦床所在。且北部既為俯側，地層較易保存，若有鐵礦當不致完全消失。北部極有發現鐵礦之希望，有待於將來之詳細調查。

鐵石分析之結果如下(百分率)(註二)

鐵 六七·四〇 磷 〇·〇六六 矽酸 一一·二七

鑛量之估計(露出部分)

平均長 約五百公尺 平均寬 約六百公尺

平均高 約二十五公尺 比重 約四

全面積以三角法計算為三二〇〇〇〇方公尺

主脈鑛量估計約為三千二百萬噸，若并北部小鑛脈及鑛砂算入

(五) 鑛產



(小鑛脈估計約為一百五十萬噸各山溝鑛砂估計為二十萬噸)三項約可得鑛石三千四百萬噸。

附產鑛物有弗石一種，形成脈狀或散佈於變質岩石中，大半皆與鐵鑛共生，其主脈若按寬一公尺長五百公尺高二十公尺比重大三計算，可得鑛石三萬噸。

此鑛成因，據初步研究，似受附近閃長岩衝出之結果，其所含有氣體及溶液侵入石灰岩中，起熱性變質而成，此論基於以下之觀察：

(一)鑛床多成脈狀與原來之層大體一致，其層面且極清晰。

(二)鑛床全部產於沉積岩中，雖距離侵入岩甚近，直接接觸處并未發現，亦未見有接觸帶鑛物如石榴石等之發生。

(三)鑛石大部分為赤鐵鑛，其他如輝鐵鑛磁鐵鑛等只佔一部分，褐鐵則成網脈狀而為風化之結果。

(四)其圍岩變質甚烈，成為一種堅硬多孔灰黃色之岩塊。在顯微鏡下觀察，則見方解石為弗石輝鐵鑛所代替，有時仍保存原有狀態之一部；除脈狀外，其晶粒并散見各變質石灰岩中。其細孔中多為玉髓瑪瑙等物所填充，圍岩中磁鐵鑛赤鐵鑛黃鐵鑛等細粒甚多，鄂博西面在鐵鑛與石灰岩之間有綠簾石一層。

就以上數點而論，本區鑛產之成因，應為溫泉上升之結果。

#### (六)結論

本區鐵鑛，鑛量之富，成分之高，已如前述。鑛床因斷層關係，大部露出於外，便於露天開採；且鑛床甚厚，鑛區集中，尤適於近代鑛業之發展，唯距出煤之區如大青山煤田等處，距離稍覺過遠，運輸方面不能不精密計劃，然此非大困難之事，唯資本稍須增加耳。苟能由該地修一鐵道聯接包頭等處，即可與平綏路啣接。則煤鐵可積於一地，非特鐵鑛可開，大青山之煤田亦可利用，實一舉而兩得其利。且包頭為內地與西北各省交通之樞紐，四通八達，東行沿平綏鐵路經察哈爾山西直到北平，南下順黃河河套可達陝西河南等省，西行經寧夏甘肅而到新疆，北上遂入外蒙而達俄境。運輸甚便，出路甚多，苟能於包頭附近建設一鋼鐵

企業，則對於西北交通應有深切之關係，其重要又不僅在經濟方面而已。

(註一)美國博物館中亞調查記第一冊柏克莫禮氏所著「蒙古消蝕面」(The Peneplanes of Mongolia)。及張席提著「蒙古地質」一兩廣地質調查所出版。

(註二)王竹泉著「綏遠大青山煤田地質」地質彙報第十號。

(註三)此次分析僅據所採標本但當時以時間關係未能作有緒統的採集故分析結果鐵分太高平均數當在百分率五十分至六十分之間。

### 附跋

右報告承著者西北科學考察團員丁道衡先生雅允，刊于本報，至為感謝。此鑛因地近邊疆有此富源，一時頗引人注意。所論鑛床成因，研究頗詳，似與皖鄂二省沿江各鑛頗為近似。果爾則鑛體形狀往往不甚規則，未可但就表面面積一概而論，故此鑛鑛量如何，實尙有待于較詳研究，方可依為根據也。

翁文灝記

# GEOLOGICAL BULLETIN

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# GEOLOGY OF YUSHAN AND KUANGFUNG OF EASTERN KIANGSI

(SUMMARY)

By P. KAO.

The area surveyed covers the two districts of Yushan and Kuangfung in eastern Kiangsi. The geological map on scale 1/200,000 (Plate II) is based on the rather inaccurate military map so far available. The geological map of the Paimen coal field in Kuangfung district on 1/50,000 (Plate I) is surveyed topographically as well by the author himself.

## STRATIGRAPHY

The stratigraphy is essentially similar to that in western Chekiang as first worked out by C. C. Liu and Y. T. Chao<sup>1</sup>. It is shown in the columnar section in Plate III and can be summarized as follows with the formations mentioned in descending order:

### ORDOVICIAN

1. *Tsiaotang series*: Black bituminous shale and sandstone + 700 m.
2. *Yushan shale* 300 m.

The following fossils of Lower Arenig have been identified:

*Phyllograptus ana* Hall  
*P. ilicifolius* Hall  
*Tetragraptus bigsbi* Hall  
*T. phylloides* Hall  
*Didymograptus extensus* Hall  
*D. hirundo* Salter  
*D. nicholsoni* Lapworth  
*Trigonograptus ensiformis* Hall  
*Dichograptus separatus* Eller  
*Mastigograptus circinalis*

3. *Tananling limestone* 290 m. It probably belongs to upper Lower Ordovician or its upper part may include lower Middle Ordovician. The fossils found include

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1. Bull. Geol. Surv. China No. 9, 1927.

*Tetragraptus bigsbi* Hall  
*Didymograptus extensus* Hall  
*Trigonograptus ensiformis* Hall  
*Orthograptus rugosus*  
*Orthograptus truncatus* Lapw.  
*Mesograptus foliaceus* Murchison

4. *Tsintsun shale and sandstone*: Exposure incomplete upper part cut by fault, probably equivalent to the Yenwashan series of western Chekiang, while the Tsiaotang, the Yushan and the Tananling series together may correspond to the Yenchapu series of Y. T. Chao.

## PERMIAN

5. *Feilaileng limestone*: Lower part cut by fault, upper part rich in brachiopoda fossils and flint.
6. *Lih sien coal series*: Over 600 m. Conformably overlying the Feilaileng limestone coal seams chiefly in middle part. The following plants have been recognized.

*Gigantopteris nicotianaefolia*  
*Pecopteris anderssonii*  
*Neuropteris* sp.  
*Alethopteris norinii*  
*Taeniopteris latecostate*  
*Cordaites* sp.

7. *Thin bed limestone*: Possibly in part Triassic.

## CRETACEOUS

8. *Wuyi formation*: The term was first created by H. S. Wang<sup>2</sup> to include both Chienteh sandstone and the interbedded and overlying volcanics. It consists in the present area of three parts: The lower one chiefly andesite and trachyte, the middle part agglomerate, red tuff-sandstone and rhyolite and the upper part mostly rhyolite and quartz-porphry.

This formation is unconformable above all other strata.

## TERTIARY?

9. *Chukiang red sandstone*: Soft sandstone and shale found in the valleys or on the slope of hills. The rocks are often used for pavement or building.

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2. Bull. Geol. Surv. China, No. 14, 1930, p. 9.

#### STRUCTURE

The structure of the Palæozoic strata consists of a series of anticlinal and synclinal folding trending NE-SW. The foldings are cut by several faults of generally the same trend but often cutting the strata obliquely. All these seem to be unconformably covered by the Wuyi formation, thus the age of the main tectonic movement is post-Palæozoic and pre-Wuyi, corresponding to the main phase of the Yenshan movement.

#### PHYSIOGRAPHY

Three stages can be distinguished.

*Hsienhsia Stage:* Old erosion plane at about or above 1000 m. mostly constituted by the Wuyi formation.

*Kungtung Stage:* Wide valleys and plains covered by the Chukiang soft sandstone. Stage of advanced maturite and deposition.

*Chükiang Stage:* Ravines and narrow gorges cut in the Chukiang red sandstone. Erosion now still in progress.

#### COAL FIELD

Coal occurs in the Lih sien series in various synclinal basins. Up to 9 seams are known to the native miners of varying thickness. The composition of coals ranges from Bm to Al. Details are given in the Chinese text. The bituminous shale of the Ordovician contains over 5% of volatile matter and is much used by the lime kilns.





# THE SULPHUR FORMS IN CHINESE COALS

BY C. H. YOUNG

1. Introduction.
2. Description of Coals Used.
3. Methods Used.
4. Analytical Results.
5. Conclusion.
6. Bibliography.

## 1. INTRODUCTION.

Methods for the analysis of total sulphur in coal have been in use for many years. It depends on the general principle of complete oxidation of the sulphur present in coal, followed by the gravimetric estimation of the sulphate as barium sulphate. From technical stand-point a total sulphur determination is useful as it fixes the value of a particular coal for particular use. However in determining the value of coking coals it is usually desirable to know not only the total sulphur content, but also how the sulphur is distributed in the coal and the exact amount of each form present. Work of this kind would be useful in indicating how much of the sulphur-containing material can be removed from the coal by washing, what effect the sulphur has on the coking value of the coal, how the various sulphur forms behave during the coking processes.

Though China is well known for her enormous resources of coal, yet no work along this line has been done, consequently no data are available so far on the exact forms of the sulphur present in the Chinese coals. It is the intention of this paper to study these forms which would be useful to those who are interested in the coking coals in the country.

## 2. DESCRIPTION OF COALS USED

The coals analyzed were all gathered from important and working mines located at different parts of the country. With a few exceptions, they are limited to good and well-known coking coals. Their total sulphur contents vary from 0.5 to over 5 per cent. The following tables (Table 1 and Table 2) give a general description of each coal used in these experiments.

TABLE 1. SOURCE OF COALS USED IN EXPERIMENTS.

Lab. No.	Province	District	County	Co. operating mine	Symbol
306	Shantung	Poshan	Hsiho	Tunghsing Co.	AB
319	Hopei	Tzuhsian	Hsitsochun	Yili Co.	Bm
321	Hopei	Tzuhsian	Hsitsochun	Yili Co.	Bh
349	Chahar	Hsuanhwa	Yutaishan	Houfeng Co.	Bl
362	Hopei	Chinghsing	Kangtouchun	Chinghsing Mining Adm.	Bm
365	Honan	An-yang	Liuhekou	Liuhekou Co.	Bm
369	Shantung	I-hsian	Tsaochuang	Chunghsing Co.	Bm
373	Hopei	Lanhsian	Chaokouchuang	Kailan Mining Adm.	Bm
374	Hopei	Lanhsian	Chaokouchuang	Kailan Mining Adm.	Bm
448	Anhwei	Hsuancheng	Tawangchun	Suitung Mine	Bl
485	Anhwei	Hwaiyuan	Shunkengshan	Hwainan Co.	BC
523	Shansi	Tatung	Kakata	—	Bl
591	Hunan	Hsiangtan	Tanchiashan	Youli Co.	Bh
597	Chekiang	Changhsing	Tameishan	Changhsing Co.	BC
655	Kiangsi	Pinghsiang	An-yuan	Pinghsiang Co.	Bl

TABLE 2. PROXIMATE ANALYSIS AND CALORIFIC VALUES OF  
COALS USED IN EXPERIMENTS.

Lab. No.	Moisture	Vol. Mat.	F. Carbon	Ash	Sulphur	Calories	B.T.U.
306	0.50%	16.81%	73.97%	6.72%	2.86%	7923	14288
319	0.24%	21.20%	72.10%	6.46%	0.65%	8153	14675
321	0.32%	21.10%	73.62%	4.96%	1.43%	8279	14902
349	1.96%	36.02%	48.38%	13.64%	0.75%	6612	11902
362	0.14%	23.70%	65.01%	11.15%	0.78%	7733	13919
365	0.46%	23.79%	60.73%	15.07%	0.84%	7355	13239
369	0.40%	31.75%	61.05%	6.80%	0.79%	8009	14416
373	0.31%	31.94%	57.39%	10.36%	0.97%	7636	13745
374	0.78%	31.27%	55.69%	12.26%	1.39%	7503	13505
448	0.10%	33.34%	46.68%	19.88%	5.47%	6348	11426
485	2.11%	36.32%	48.67%	12.90%	1.66%	6646	11963
523	2.00%	35.63%	58.11%	4.26%	0.57%	7791	14029
591	0.62%	22.03%	70.98%	6.37%	0.65%	8125	14625
597	0.48%	33.49%	45.51%	20.52%	3.35%	6180	11124
655	0.92%	30.38%	53.03%	15.67%	0.54%	7219	12994

### 3. METHODS USED.

The method developed by Powell and Parr\* has been well known and considered as a reliable and practical procedure. For that reason, their method was entirely adopted for this study. The procedure is abstracted below.

#### 1. Total Sulphur Content.

One gram, or, preferably, the factor weight, 1.3736 grams, of the coal sample is heated with about three grams of Eschka mixture (one part of anhydrous sodium carbonate, two parts of calcined magnesium oxide and one-fifth part of ammonium nitrate) in a muffle furnace and the sulphur is determined in the water extracts as sulphates by barium chloride method. In case the sulphur content is exceedingly high, say over two per cent., one half the factor weight, 0.6868 gram, is used.

#### 2. Total Inorganic Sulphur Content.

One gram of the sample is digested with 80 cc. of dilute nitric acid (1:3) with occasional addition of bromine water for a period of 24 hours at room temperature. The filtrate, after getting rid of the nitric acid by evaporating with hydrochloric acid, is taken up in dilute hydrochloric acid and treated with ammonium hydroxide to precipitate iron and the latter is determined by potassium permanganate titration. The sulphur is determined by usual method from the filtrate from which the iron is just removed. This amount of iron, in per cent., is termed as the nitric acid soluble iron content of the coal while that of sulphur, also in per cent., is known as the total inorganic sulphur content, that is, the pyritic sulphur plus sulphate sulphur.

#### 3. Sulphate Sulphur Content.

A five-gram portion of the sample is extracted with 300 cc. of dilute hydrochloric acid (3%) for a period of 40 hours at a temperature of about 60°C. The extract is analyzed for iron and sulphur, the sulphur representing the sulphate sulphur present in the coal.

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\* Forms in which Sulphur Occurs in Coal. By A. R. Powell and S. W. Parr. Bull. Am. Inst. Mining Met. Eng. 1919, 2041-9; C. A. XIV, 112.  
The Analysis of Sulphur Forms in Coal. By A. W. Powell. U. S. Bureau of Mines, Technical Paper 254.

#### 4. Pyritic Sulphur Content.

The per cent. of the pyritic sulphur in coal may be found in two ways, namely:

- a. By subtracting the per cent of sulphate sulphur from the per cent of total inorganic sulphur.
- b. By calculating from pyritic iron content of the coal. The difference between nitric acid soluble iron and hydrochloric acid soluble iron is the pyritic iron content and by means of the latter the pyritic sulphur is readily computed.

#### 5. Total Organic Sulphur Content.

The total organic sulphur content of the coal may be estimated as follows:

- a. By difference. The per cent. representing the sulphate sulphur in the coal is added to the correct per cent. representing the pyritic sulphur, and the sum is subtracted from the per cent., representing the total sulphur in the coal.
- b. By direct determination. The sulphur is determined by Eschka method from the residue of the dilute nitric acid extraction.

#### 6. Two forms of Organic Sulphur.

One gram, or the factor weight, 1.3736 grams, of the coal sample is extracted with 25 cc. of phenol at a temperature of about 150°C. for twenty hours. The mass is filtered hot and washed with alcohol and sulphur is determined from the residue by Eschka method. This amount of sulphur, in per cent, represents the phenol insoluble, non-phenolic, sulphur of the coal, while the per cent of the phenol soluble, phenolic, sulphur is obtained by subtracting the per cent of non-phenolic sulphur from the total sulphur content of the coal. The total organic sulphur minus the phenolic, resinous organic, sulphur both represent in per cent, gives the per cent of humus organic sulphur.

### 4. ANALYTICAL RESULTS OF EXPERIMENTS.

1. The first set of experiments was, of course, the determination of the total sulphur in coal, the data of which were already given in Table 2. Now comes the second which was performed with regard to the analysis of the sulphate and pyritic

forms of the sulphur alone. The data from these experiments are given in the following table (Table 3).

TABLE 3. SULPHUR AND IRON IN COAL AND ALSO WITH A COMPARISON OF THE PYRITIC SULPHUR AS OBTAINED WITH THE PYRITIC SULPHUR AS CALCULATED FROM THE PYRITIC IRON CONTENT:—

Lab. No.	Inorg. Sulphur	SO <sub>2</sub> Sulphur	Pyritic Sulphur	HNO <sub>3</sub> Sol. Fe	HCl Sol. Fe	Pyritic Iron	Pyritic Sulphur	Differ.
306	1.40%	0.25%	1.15%	1.83%	0.86%	0.97%	1.11%	+0.04%
319	0.11%	0.02%	0.09%	0.23%	0.14%	0.09%	0.10%	-0.01%
321	0.92%	0.08%	0.84%	0.88%	0.18%	0.70%	0.80%	+0.04%
349	0.49%	0.06%	0.43%	0.59%	0.22%	0.37%	0.42%	+0.01%
362	0.25%	0.02%	0.23%	0.40%	0.20%	0.20%	0.23%	0.00%
365	0.32%	0.08%	0.24%	0.46%	0.27%	0.19%	0.22%	+0.02%
369	0.25%	0.23%	0.02%	0.55%	0.53%	0.02%	0.02%	0.00%
373	0.30%	0.12%	0.18%	0.42%	0.30%	0.12%	0.14%	+0.04%
374	0.60%	0.17%	0.43%	0.68%	0.32%	0.36%	0.41%	+0.02%
448	3.88%	0.05%	3.83%	3.64%	0.27%	3.37%	3.86%	-0.03%
485	1.04%	0.07%	0.97%	1.00%	0.16%	0.84%	0.96%	+0.01%
523	0.12%	0.00%	0.12%	1.57%	1.50%	0.07%	0.08%	+0.04%
591	0.00%	0.00%	0.00%	0.19%	0.18%	0.01%	0.01%	-0.01%
597	1.77%	0.22%	1.55%	1.75%	0.42%	1.33%	1.52%	+0.03%
655	0.10%	0.00%	0.10%	0.35%	0.28%	0.07%	0.08%	+0.02%

It is claimed that a small quantity of organic sulphur may have been taken into solution by dilute nitric acid. According to the present data it seems correct since the per cent of pyritic sulphur obtained by direct extraction method are generally higher than those calculated from the pyritic iron content. For this reason the latter figures are considered as the correct per cent of the pyritic sulphur in coal.

2. Total Organic Sulphur. The following table (Table 4) gives the per cent of total organic sulphur obtained in two ways. A comparison of the totals and their average values are also given.

TABLE 4. PER CENT REPRESENTING TOTAL ORGANIC SULPHUR:—

Lab. No.	Total Sulphur	Pyritic Sulphur	SO <sub>4</sub> Sulphur	Total By diff.	Organic S. Dir. Det.	Difference	Average
306	2.86%	1.11%	0.25%	1.50%	1.48%	+0.02%	1.49%
319	0.65%	0.10%	0.02%	0.53%	0.56%	-0.03%	0.55%
321	1.43%	0.80%	0.08%	0.55%	0.52%	+0.03%	0.54%
349	0.75%	0.42%	0.06%	0.27%	0.28%	-0.01%	0.28%
362	0.78%	0.23%	0.02%	0.53%	0.57%	-0.04%	0.55%
365	0.84%	0.22%	0.08%	0.54%	0.52%	+0.02%	0.53%
369	0.79%	0.02%	0.23%	0.54%	0.56%	-0.02%	0.55%
373	0.97%	0.14%	0.12%	0.71%	0.69%	+0.02%	0.70%
374	1.39%	0.41%	0.17%	0.81%	0.82%	-0.01%	0.82%
448	5.47%	3.86%	0.05%	1.56%	1.60%	-0.04%	1.58%
485	1.66%	0.96%	0.07%	0.63%	0.60%	+0.03%	0.62%
523	0.57%	0.08%	0.00%	0.49%	0.46%	+0.03%	0.48%
591	0.65%	0.01%	0.00%	0.64%	0.63%	+0.01%	0.64%
597	3.35%	1.52%	0.22%	1.61%	1.58%	+0.03%	1.60%
655	0.54%	0.08%	0.00%	0.46%	0.46%	0	0.46%

## 3. Two Forms of Organic Sulphur.

TABLE 5. PHENOLIC AND HUMUS ORGANIC SULPHUR IN COAL:—

Lab. No.	Total Sulphur	Nonphenolic Sulphur	Phenolic Sulphur	Aver. Total Org. sulphur	Humus Org. Sulphur
306	2.86%	2.72%	0.14%	1.49%	1.35%
319	0.65%	0.64%	0.01%	0.55%	0.54%
321	1.43%	1.42%	0.01%	0.54%	0.53%
349	0.75%	0.70%	0.05%	0.28%	0.23%
362	0.78%	0.72%	0.06%	0.55%	0.49%
365	0.84%	0.76%	0.08%	0.53%	0.45%
369	0.79%	0.59%	0.20%	0.55%	0.35%
373	0.97%	0.77%	0.20%	0.70%	0.50%
374	1.39%	1.15%	0.24%	0.82%	0.58%
448	5.47%	5.03%	0.44%	1.58%	1.14%
485	1.66%	1.52%	0.14%	0.62%	0.48%
523	0.57%	0.56%	0.01%	0.48%	0.47%
591	0.65%	0.57%	0.08%	0.64%	0.56%
597	3.35%	2.86%	0.49%	1.60%	1.11%
655	0.54%	0.48%	0.06%	0.46%	0.40%

According to the above table the majority of organic sulphur would be of humus type.

## 4. Summary of Analytical Results.

The following table gives in condensed form the results of the analyses for the various forms of sulphur and a comparison of the total of these with the total sulphur in the coal.

TABLE 6. SUMMARY OF ALL ANALYSES FOR SULPHUR FORMS IN COAL:—

Lab. No.	Pyritic Sulphur	SO <sub>4</sub> Sulphur	Humus Org. Sulphur	Phenolic Sulphur	sum	Total Sulphur	Total Difference
306	1.11%	0.25%	1.35%	0.14%	2.85%	2.86%	-0.01%
319	0.10%	0.02%	0.54%	0.01%	0.67%	0.65%	+0.02%
321	0.80%	0.08%	0.53%	0.01%	1.42%	1.43%	-0.01%
349	0.42%	0.06%	0.23%	0.05%	0.76%	0.75%	+0.01%
362	0.23%	0.02%	0.49%	0.06%	0.80%	0.78%	+0.02%
365	0.22%	0.08%	0.45%	0.08%	0.83%	0.84%	-0.01%
369	0.02%	0.23%	0.35%	0.20%	0.80%	0.79%	+0.01%
373	0.14%	0.12%	0.50%	0.20%	0.96%	0.97%	-0.01%
374	0.41%	0.17%	0.58%	0.24%	1.40%	1.39%	+0.01%
448	3.86%	0.05%	1.14%	0.44%	5.49%	5.47%	+0.02%
485	0.96%	0.07%	0.48%	0.14%	1.65%	1.66%	-0.01%
523	0.08%	0.00%	0.47%	0.01%	0.56%	0.57%	-0.01%
591	0.01%	0.00%	0.56%	0.08%	0.65%	0.65%	0.00%
597	1.52%	0.22%	1.11%	0.49%	3.34%	3.35%	-0.01%
655	0.08%	0.00%	0.40%	0.06%	0.54%	0.54%	0.00%

It is evident from this table that the sum of the several analyses checks very closely with the total sulphur content of each coal.

## 5. CONCLUSION.

1. The organic sulphur content of coal is generally known to be greater than pyritic sulphur content. This statement is proved to be correct with Chinese coals.
2. The method of Powell and Parr is well applicable to Chinese coals and values on duplicate determinations mutually agree.
3. Dilute nitric acid will extract small amounts of organic sulphur from certain coals. In order to avoid this error in laboratory determinations, it is recommended that the pyritic sulphur be calculated from the pyritic iron content.

4. Pyrite in coal can be quantitatively extracted by the same acid.
5. Semibituminous coals and the low volatile bituminous coals must be digested for a longer time with concentrated nitric acid in order to render the organic matter completely soluble in ammonia.
6. The percentages of phenolic sulphur are always lower than those of humus organic sulphur.

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# THE USE OF CALCIUM HYDROXIDE AND SODIUM NITRATE IN THE DETERMINATION OF TOTAL SULPHUR IN COAL

BY C. H. YOUNG

1. Introduction
2. Theoretical basis
3. Preparation of the flux
4. Description of coals used in the experiments
5. Notes on the procedures
6. Results of experiments
7. Conclusion.

## 1. INTRODUCTION.

The Eschka method for the determination of total sulphur in coal was first introduced as early as 1870 (1). More than three scores of years have elapsed, yet no better method has been proposed. Though both of the bomb washing and sodium peroxide methods (2) were mentioned by some fuel chemists as to give results in close agreement with the Eschka method, they are by no means better than the Eschka's. Consequently the latter has long been universally recognized as the best method and is adopted by many scientific institutions in the world as the standard method for total sulphur estimation in coals. If not for its expense, Eschka method should be accepted as the best one among all that have been proposed so far. It is expensive not only because of the high market price of the light magnesium oxide but also of the heat energy consumed during the fusion. The latter factor was always required practically for all the methods mentioned in the literature and it seems that no better method other than fusion is available in attacking the coal substance. The other factor, that is, the high cost of the light magnesium oxide, can however be replaced by using some cheaper reagent. Among the other methods, the one proposed by Ivison (3) seems to be most reliable. The author has tried the Ivison method for the determination of total sulphur in some Chinese coals and found that the sintered coal and the chemical mixture are liable to form a hard cake which is difficult to break up. A mixture consisting of calcium hydroxide and sodium nitrate

is recommended with the prime aim of lowering the cost for sulphur determination in coals. The results obtained from such a flux as mentioned are pretty close to those by the Eschka method.

## 2. THEORETICAL BASIS.

The methods for determination of total sulphur in coal are based upon the principle of complete oxidation of the sulphur-bearing materials to sulphates and the latter are estimated as barium sulphate. The process of oxidation is usually carried out in two stages. The first stage is that the sulphur is oxidized by a suitable oxidizing agent and then the second stage, the resultant sulphur oxides are absorbed by an efficient absorbent, which is generally performed by a basic substance against the acidic property of the sulphur oxides. The methods given in the literature may be classified as follows:

1. Air plays as an oxidizing agent and a basic substance is employed as an absorbent of the sulphur oxides formed. This is exemplified by the Eschka method and Ivison method.

2. Oxygen gas performs the oxidation while water or caustic alkali, the absorption. Example, bomb washing method.

3. A single suitable flux is employed both as an oxidizing agent and absorbent. Sodium peroxide method (2) is of this type.

4. Different chemicals are employed as oxidizing agent and absorbent respectively. Potassium permanganate method (4, 5, 6) belongs to this class.

The use of the mixture of calcium hydroxide and sodium nitrate as a flux is of the last class, that is, sodium nitrate plays in part as an oxidizing agent while the calcium hydroxide serves as an absorbent.

The use of sodium nitrate in the mixture seems, for the first glance, quite objectionable to the subsequent precipitation of the sulphates as barium sulphate; as the latter is partially soluble in dilute nitric acid (7). But the fact is that the sodium nitrate is unstable at high temperature and is decomposed during the fusion into sodium nitrite with evolution of free oxygen and the sodium nitrite thus formed is also unstable at high temperature and splits into oxides of sodium and nitrogen (8). Since the temperature of the furnace is so high, always exceeding 900° C., that the

evolved nitrogen oxides are unable to combine with the lime of the flux and set free as they are, so the resultant fused mass is not expected to contain any nitrate or nitrite ions.

The author made tests on the fused mass for nitrate and nitrite with saturated ferrous sulphate solution and concentrated sulphuric acid and found that there is no detectable nitrate or nitrite ions. But he suspected that the tests were not conclusive and made several careful determinations assuming that the nitrate or nitrite is present as follows:—

The water extracts of the fusion was treated with bromine water and considerable excess of hydrochloric acid and evaporated to dryness on water bath in order to get rid of the nitric acid. The residue is taken up with dilute hydrochloric acid and sulphur is determined by usual method. The results thus obtained were just the same as those obtained from the mass without treatment of excess hydrochloric acid and evaporation. The absence of the nitrate or nitrite ions in the used mass is thus confirmed.

### 3. PREPARATION OF THE FLUX.

The author made a number of trials in estimating the correct proportion of the ingredients of the flux, that is, calcium hydroxide and sodium nitrate and found that the flux is best prepared by mixing three parts of finely pulverized slaked lime of superior quality with one part of pure sodium nitrate, also finely pulverized. When less amount of sodium nitrate is used it is found that incomplete oxidation of the sulphur resulted. And conversely, less slaked lime (or more sodium nitrate) is employed the fusion will cake as in the Ivison method and the results obtained are by no means better than the proportion quoted above.

Quick lime can, of course, be used as well as the slaked lime but when pulverized the quick lime is of a dense powdery mass which is not suitable, in the author's opinion, for the absorption of gases.

### 4. DESCRIPTION OF COALS USED IN EXPERIMENTS.

The samples are collected so as to cover all classes of coals, that is, from high rank anthracite, Ah, to lignite, C. In addition the coals are almost of all geological ages. The contents of sulphur range from 0.15 to 7.41 per cent. The descriptions of the samples are tabulated as in Table I:—

TABLE 1.—THE SOURCES OF COALS USED.

Sample No.	Province	District	County	Mine, Co. etc.	Geol. ages	Symbol
335	Liaoning	Hsian	———	Tai Lai Mine	Cretaceous	Bm
450	Anhwei	Tsinghsien	Yenkungtang	———	Permian	Bm
479	Hopei	Wanping	Mentoukou	Chung Ying Co.	Jurassic	Ah
514	Yunnan	Chengkiang	Haipakeng	———	Permo-Car- boniferous	Bm
517	„	A-Mi	Wukeh	———	„	BC
531	Suiyuan	Kooyang	Wehhsinhao	———	Jurassic	BC
563	Szuchuan	Ya-an	Kuanyinpu, Taotzeping	———	„	Am
574	„	Hanyuan	Niushihpo, Yangtzechiao	———	„	AB
607	Anhwei	Hsuancheng	Tawangchun	Sui Tung Mine	Permo-Car- boniferous	Bl
641	Hopei	Lincheng	———	Lin Cheng Mine	„	BC
668	Hunan	Hsianghsiang	Hungshantien	Kuang Yu Co.	Permian	AB
694	Shansi	Huenyuan	Taoshahchun	———	Jurassic	BC
732	Kuangtung	Lochang	Lochiatu	———		Bm
740	„	Chinhsien	Kuchahling	———	Tertiary	C
743	„	Chiungshan	Chiatzeshih, Niushihshan	———	Permian	C
763	Hunan	Hsianghsiang	Ngenkou, Hweilungshan	Tien Pao Yu Co.	„	Bm
813	Shantung	Ningyang	———	Hwa Feng Co.		BC
815	Kiangsu	Tungshan	Chiawang	Hwa Tung Co.	Permo-Car- boniferous	Bl
820	Anhwei	Suhsien	———	———	„	Bh
841	Kiangsi	Loping	Mingshan	Lo Ping Mine	Permian	C
845	Honan	Yuhsien	Sanshanfeng	———	Permo-Car- boniferous	Bh
853	Shensi	Hancheng	Chiaoerkou	———		Bh
863	Chekiang	Kiangshan	Lihsien	Cheng Tang	Permian	Bh
886	Hupei	Tsingmen	Kuanmiaoping	———	Jurassic	Al

5. NOTES ON THE PROCEDURES.

1. The author in performing these analyses followed, with modifications, the procedure published by the American Society of Testing Materials (A.S.T.M.) for total sulphur determination in coal by Eschka method.

2. During the fusion a high-form porcelain crucible of 30 cc. in capacity is employed.

3. In extraction the fusion is not necessarily brought in to the beaker and digested with boiling water. The author proceeds as follows: The fused mass is crushed, if necessary, and transferred directly to a filter paper. The small particles adhering to the sides of the crucible are moistened with hot water. When they are readily detached with a glass rod and are transferred to the filter. The crucible is washed 4 or 5 times with hot water, scrubbed with a policeman, and the washings are poured on the filter. The paper and the contents are washed to the complete removal of sulphates.

4. During the digestion and washing of the fusion on the filter the present method takes slightly longer time than the Eschka method.

5. Examine the residue for sulphur after digestion, by dissolving it in hydrochloric acid and treating with bromine water and barium chloride solution. When an appreciable amount of sulphur is found, add it to the main precipitate. If the procedure is followed promptly there should be no detectable sulphur in the residue, and this recovery is unnecessary.

6. The filtered extracts from the present method are always rendered extremely turbid by calcium salts, which is soluble in acid in subsequent treatment and it does not interfere with the precipitation of sulphur as barium sulphate.

7. The addition of bromine water may be omitted when the present method is employed, but a little is always added as a precaution.

8. Always run a blank determination with each analysis, using the same amount of all reagents that were employed in the regular determination. Deduct the sulphur found in the blank from the amount found in the sample.

9. Determinations of ash in coal or coke must not be made in the same muffle at the same time with sulphur determination, since during the ashing process sulphur compounds are more or less evolved as gases that may be in turn absorbed by the flux for sulphur determination.

## 6. RESULTS OF EXPERIMENTS.

Lab. No.	Sample Number	Eschka Method	Present Method	Difference
1	335	0.72%	0.77%	+0.05%
2	450	0.41%	0.41%	0
3	479	0.15%	0.17%	+0.02%
4	514	6.05%	5.87%	-0.18%
5	517	7.41%	7.30%	-0.11%
6	531	3.39%	3.30%	-0.09%
7	563	0.63%	0.62%	-0.01%
8	574	0.60%	0.60%	0
9	607	3.94%	3.86%	-0.08%
10	641	2.66%	2.62%	-0.04%
11	668	0.62%	0.64%	+0.02%
12	694	0.72%	0.72%	0
13	730	3.31%	3.22%	-0.09%
14	740	3.73%	3.73%	0
15	743	1.33%	1.26%	-0.07%
16	763	3.29%	3.23%	-0.06%
17	813	5.28%	5.26%	-0.02%
18	815	0.59%	0.59%	0
19	820	0.86%	0.85%	-0.01%
20	841	2.18%	2.08%	-0.10%
21	845	0.46%	0.48%	+0.02%
22	853	0.47%	0.48%	+0.01%
23	863	1.12%	1.14%	+0.02%
24	886	0.53%	0.56%	+0.03%

## 7. CONCLUSION:

1. The method proposed by the author is almost as good as the Eschka's when the sulphur content of the coal is below 3 per cent.; while for coals of higher sulphur content the method gives generally a slightly lower result in comparison with the Eschka method. As the maximum difference in per cent. is only 0.18 in 6.0 per cent. (about 3 per cent. error) which seems allowable in the usual course of analysis.

2. This method is also preferable to the Eschka's for the reason that the market price of slaked lime is much cheaper than that of light magnesium oxide.

(MgO, G.\$3.50 per pound; Ca (OH)<sub>2</sub>, G.\$1.30 per pound.) Sodium carbonate and sodium nitrate are of the same price, approximately.

3. During the digestion and washing of the fusion on the filter this method takes slightly longer time than the Eschka method.

4. The volume of light magnesium oxide is much looser than that of slaked lime and this property is favorable to the absorption of evolving gases as it gives more surfaces and takes better care of them. It is of this reason for the author to use slaked lime instead of quick lime.

5. Since sodium nitrate in the mixture and the resulted nitrite will completely decompose during the fusion, no nitrate ions are found in the solution from which the barium sulphate is to be precipitated.

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# SOLVENT EXTRACTION OF CHINESE BITUMINOUS COALS

BY K. PING

1. Introduction
2. Coal Samples
3. Description of the Coking Properties
4. Experimental
5. Results
6. Discussion of Results
7. Relation between Moisture Combined Ratio and the Gamma Content.
8. Relation between the Geological Age and the Gamma Content.
9. Geological Age and the Coalification of Coals as Influences on their compounds.
10. Summary

## 1. INTRODUCTION.

Since De Marsilly systematically studied the extraction of some of the organic compounds in coal by means of benzene, alcohol, ether, carbon disulphide and chloroform, the solvent extraction has attracted sufficient attention of many coal investigators, who endeavored to find the chemical composition of coal. However, in spite of many theories that were deduced from the results of their research, the chemical constitution of coal still remains obscure and speculative.

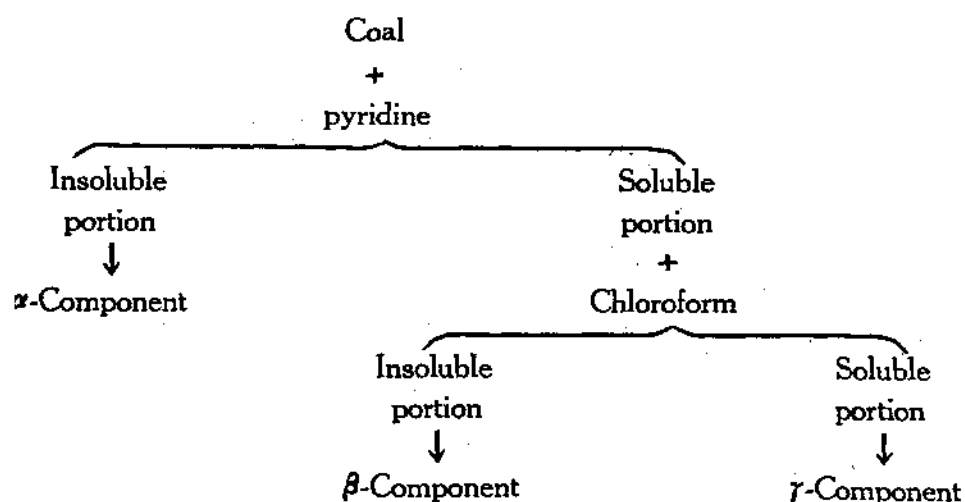
Among the organic solvents used for the extraction pyridine, which was first used by Bedson,<sup>1</sup> proved to be the best. The strong solvent properties of pyridine on coal, as stated by Hargar<sup>2</sup> is however not merely a physical action but a chemical process which depolymerizes the polymeric compounds of coal into simpler ones easily soluble. Wheeler<sup>3</sup> and Clark showed moreover, that the pyridine extract can be further divided by the treatment of chloroform, and termed the components thus separated by the two solvents as follows:—

$\alpha$ -Component—The portion of coal which does not dissolve in pyridine.

$\beta$ -Component—The portion which is soluble in pyridine but not in chloroform.

$\gamma$ -Component—The portion which is soluble in both solvents.

The separation is shown more clearly in the following diagram.



The alpha and beta compounds are supposed to be of the same type of substance which was derived from the plant remains, while the gamma compounds are considered to be of resinic nature. It is generally believed that, in the carbonisation of coal, the gamma compounds impart the agglutinating action and play the most important part in the coke formation.

In view of the great range of variation in the Chinese bituminous coals as to their coking properties, different methods have to be used in order to determine these coking properties in the laboratory with small samples of coal prior to the utilization on an industrial scale. It is the purpose of this study to test coals by means of solvents with the aim to see how they influence on their caking properties.

## 2. COAL SAMPLES.

Sixteen coal samples from important mines were chosen for the test. Their sources, geological age and proximate analysis on dry and ash free basis are herein tabulated below:

Lab. No.	Locality	Company	Geological Age	Vol. Mat.	Fixed Carbon
321	Tsuhsien, Hopei	Yili	P-C	22.28	77.72
319	" "	Yili	"	22.72	77.28
310	Poshan, Shantung	Potung	"	25.67	74.63
309	" "	"	"	24.00	76.00
365	Liuhokou, Honan	—	"	28.15	71.85
362	Chinghsing, Hopei	Chinghsing	"	26.72	73.28
374	Lanhsien, Hopei,	K. M. A.	"	35.96	64.04
373	" "	"	"	35.76	64.24
369	Ihsien, Shantung,	Chunghsing	"	34.21	65.79
587	Shunkengshan, Anhui	Tatung	"	38.75	61.25
591	Hsiangt'an, Hunan	Yiuli	P	23.69	76.31
597	Changhsing, Chekiang,	Changhsieng	"	42.39	57.61
448	Hsuancheng, Anhui	—	"	41.66	58.34
655	Pinghsiang, Kiangsi	Pinghsiang	J	36.42	63.58
349	Hsuanhua, Chahar,	Houfeng	"	42.68	57.32
523	Tatung, Shansi	—	"	38.01	61.99

P-C = Permo-Carboniferous

P = Permian

J = Jurassic

### 3. DESCRIPTION OF THE COKING PROPERTIES

Nos. 321 and 319 (Tsuhsien) are obtained from different seams of a same mine. They all form coherent semi-cokes, but 319 is slightly shrinking and 321 more or less swelling.

Nos. 309 and 310 (Poshan) are used for coke production by native method as well as by modern coke oven process. No. 309 produces a highly swelling semi-coke, lustrous, hard and porous. No. 310 produces a slightly swelling hard semi-coke.

No. 365 (Liuhokou) is used to produce coke with a production of more than 10,000 tons annually. The semi-coke is swollen, hard and lustrous.

No. 362 (Chinghsing) on heating shrinks to a very hard and compact semi-coke. It is used in by-product coke ovens of Chinghsing Mining Administration with a maximum daily capacity of about 110 tons.

No. 373 and 374 (Kailan) yield slightly swollen semi-coke, hard and lustrous, and have been used to produce coke in bee-hive ovens.

No. 369 (Chunghsing of Ihsien) gives a highly swelling coke, porous but friable. This coal is carbonized in native coke ovens with a monthly production of about 3200 tons.

No. 587 (Shunkengshan) The semi-coke from it is hard, compact and slightly shrinking, considered as not good coking.

No. 591 (Hsiangtan) gives a non-swelling coherent semi-coke, and cokes produced in native ovens are said to be of good quality.

No. 597 (Changhsing) produces a very highly swelling coke, lustrous and porous.

No. 448 (Hsuancheng) gives a highly swelling semi-coke, porous and friable, but it suffers the disadvantage of very high sulphur content.

No. 655 (Pingsiang) gives a coherent and moderately hard semi-coke, with a slight shrinkage. It had been used on a large scale for the manufacture of metallurgical coke.

No. 523 (Tatung) is rich in fusain content which probably renders the coal unsuitable for the production of coke. However, it cakes slightly, and yield a loosely bound semi-coke which crumbles easily into powder.

No. 349 (Hsuanhua) is entirely non-coking but rich in volatile matter.

#### 4. EXPERIMENTAL

A procedure for carrying out the extraction of coal by pyridine was described by Illingworth<sup>2</sup>. He used a five-gram sample in an all-glass joint Soxhlet apparatus. The extraction however requires a long time of about one week or two. Moreover, owing to the prolonged heating the compounds in the extract tend to polymerize again to form a film of gummy substance which adheres firmly on the inner surface of the flask and is hard to remove even with fresh pyridine. A modified method employed by U. S. Bureau of Mines is consequently adopted.

The samples were made to pass through a 60-mesh sieve and dried at 105°C for two hours. A one-gram portion of each was mixed with four to five volumes of clean sand in an alundum thimble, and was extracted with 125 cc. of pyridine in an all-glass joint Soxhlet extractor in an atmosphere of nitrogen. The extraction was

so regulated that the syphon of extract occurred once in about ten minutes, and was continued for 48 hours. In order to remove the coal particles which might be carried over by pyridine, the extract was filtered into a tared 150 cc. pyrex florence flask. The filtered extract was then concentrated by distilling off the pyridine until the content tends to splash up. The pyridine remaining in the flask was removed by repeated evaporation with portions of 15 cc. of xylene. After the removal of pyridine, the flask was heated in a vacuum oven at 105°-110°C to drive out xylene. Then the flask was cooled in a desiccator, and weighed. The increase in weight represents the amount of beta and gamma compounds in the coal.

The dried pyridine extract which contained the beta and gamma compounds was broken up with a glass rod, washed with chloroform and poured into the thimble already in the Soxhlet extractor. The adhering particles on the flask were removed with a policeman and rinsed out again with chloroform into the thimble. Fresh chloroform was added to the extractor to a volume of about 125 cc. The extraction was proceeded in the same way as that with pyridine, until the descending solvent was colorless. The extract was filtered into a flask previously weighed and distilled off the major portion of chloroform. Then it was dried in vacuo at 105°C to constant weight. The amount of gamma compounds is obtained by difference again.

## 5. RESULTS.

The following results were recorded on ash-free basis:

Coal	Pyridine Extract	Alpha Compd.	Beta Compd.	Gamma Compd.
321	2.74	97.26	0.46	2.28
319	3.95	96.05	1.29	2.66
310	6.82	93.18	2.03	4.79
309	7.24	92.76	0.66	6.58
365	6.07	93.93	2.39	3.68
362	6.37	93.63	1.74	4.63
374	29.41	70.59	18.09	11.32
373	32.72	67.28	16.95	15.77
369	32.75	67.25	16.33	16.42
587	11.12	88.88	4.85	6.27
591	7.73	92.27	2.97	4.76
597	18.75	81.25	8.63	10.12
448	19.21	80.79	7.93	11.28
655	23.44	76.56	13.52	9.92
349	14.51	88.49	6.07	8.44
523	19.52	80.48	10.36	9.16

## 6. DISCUSSION OF RESULTS.

In order to facilitate the discussion of the results certain factors listed below must be taken into consideration.

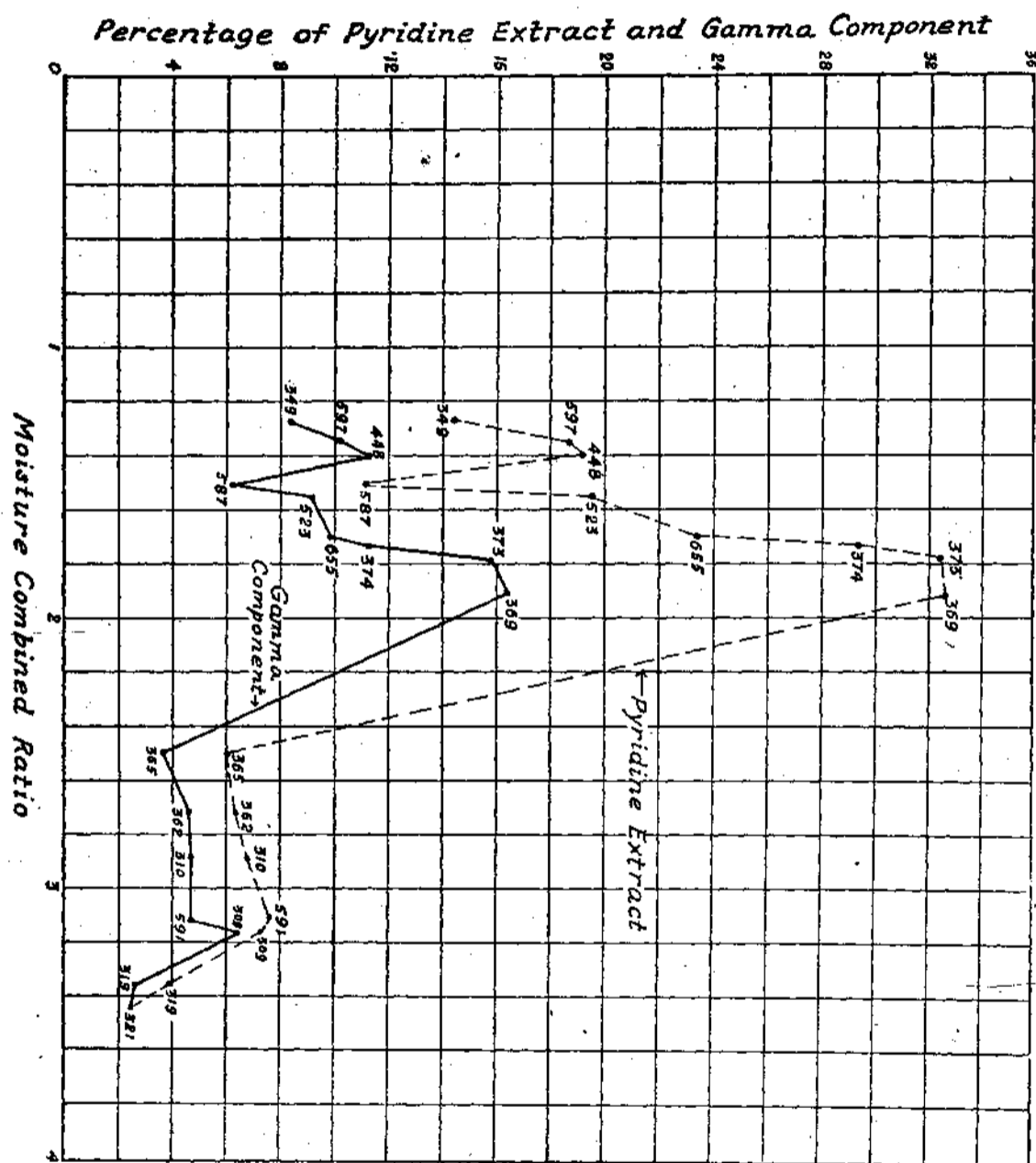
Coal	Age	Notation	Moisture <sup>5</sup> combining ratio	Gamma Compd.	Oil yield <sup>6</sup>	Swelling coefficient.
321	P-C	Bh	3.44	2.28	5.73	1.06
319	"	Bh	3.37	2.66	4.97	—
310	"	Bm	2.88	4.79	5.70	1.04
309	"	Bh	3.16	6.58	5.05	1.40
365	"	Bm	2.50	3.68	5.92	1.04
362	"	Bm	2.72	4.63	6.65	0.90
374	"	Bm	1.73	11.32	10.50	1.14
373	"	Bm	1.78	15.77	9.76	1.96
369	"	Bm	1.90	16.42	8.05	2.56
587	"	Bl	1.51	6.27	12.10	0.94
591	P	Bh	3.12	4.76	4.65	1.00
597	"	Bl	1.34	10.12	7.59	2.72
448	"	Bl	1.39	11.28	8.37	2.64
655	J	Bl	1.69	9.92	9.15	1.00
349	"	Bl	1.27	8.44	10.50	1.00
523	"	Bl	1.55	9.16	11.05	1.00

## 7. THE RELATION BETWEEN MOISTURE COMBINED RATIO AND THE GAMMA CONTENT.

By moisture combined ratio is meant the ratio of fixed carbon to the sum of moisture and volatile matter. It is the common opinion that this ratio shows the degree of coalification of coals in that it increases with the increase of the latter. Two curves obtained by plotting the gamma content and pyridine extract against the moisture combined ratio are shown herewith.

The curves though appearing in a zigzag manner seem to show that the degree of coalification has a striking influence on the pyridine and chloroform extract. Of course, there seems to be no definite relationship existing between each other but it is evident that as the moisture combined ratio is higher, that is the coalification is increased, the difference among the gamma contents is very

much smaller. Among the coals studied, Nos. 523, 587 and 349 have been known to be of very poor caking quality, Nos. 448, 597 and 591 are of doubtful caking quality, while the rest of them are all good caking coals and have actually producing cokes in the market. It is therefore quite probable that among the bituminous coals of lower coalification, the gamma content is very important to the caking quality.



Moreover, it is interesting to note that those coals which locate on the paramount points of the gamma curve, swells greatly on heating. The coals of that category are:—Nos. 597, 448, 373, 369 and 309. On the contrary, the coals that lie on the lower part of the curve are not greatly swelling, or non-swelling or even shrinking on heat treatment. Thus, it seems that there is a natural grouping of the coals. In each group the coal which gives a higher gamma content is comparatively more swelling on heating.

#### 8. THE RELATION BETWEEN THE GEOLOGICAL AGE AND THE GAMMA CONTENT.

Without considering the coalification as measured by the moisture combined ratio, the gamma contents of the coal seem to bear no relation to the caking property at all. A non-coking coal like No. 349 gives 8.44% of gamma but a good coking coal like No. 321 gives only 2.28% of the chloroform extract. However, the result is also of interest if the coals are assorted into groups according to their geological age, and gives evidence that the gamma compounds really impart their cementing influence in the formation of coke.

Thus, among the Jurassic coals, No. 655 which is good coking and has been used for coke producing, contains 9.92% of gamma. No. 523 which is poor coking contains 9.16% and No. 349 which is non-coking contains still less, only 8.44%. In the Permian coals, the relation holds true too. No. 597 and 448 which yield very highly swelling semi-cokes have gamma contents of 10.12% and 11.28% respectively. And, No. 591 contains 4.76% of gamma yield a non-swelling semi-coke. Among the coals of Permo-Carboniferous age, No. 369 which forms a highly swelling coke, contains 16.42% of gamma compound. Next to it are No. 373 and 374 which contain 15.77% and 11.32% of gamma respectively. The rest of the coals except No. 587 6.27%, all form coke on heating with little swelling, and contain much less gamma compounds than Nos. 374 & 369.

#### 9. THE GEOLOGICAL AGE AND THE COALIFICATION OF COALS AS INFLUENCES ON THEIR COMPOUNDS.

Now the problem arises: why Jurassic coals like No. 349 and 523 which are rich in gamma component have poorly coking properties, but Permo-carboniferous coals such as Nos. 320 and 321 contain much less gamma compounds and are good coking? It seems that the gamma contents of various coals are different in composi-



tion. The gamma compounds are proved to be of resinic nature and are supposed to be derived from the resin in wood or plant remains, as a result of polymerisation. As a rule, the polymerisation of a compound, depends on aging, temperature, pressure or catalytic action of foreign materials. It is self-explanatory, that the polymers are greater in molecular weight than the original compounds, and consequently their melting point and boiling point are higher. It is the same case with the gamma compounds. The more they were aged and the higher the degree of coalification; the more they polymerize and hence the higher their boiling point.

In the process of carbonisation the gamma compounds are decomposed into simpler compounds as gases, oils, tars and also compounds of still higher carbon content which cement the coal particles to form coke. It is obvious that the gamma compounds of lower molecular weight volatiles more easily and escape from serious decomposition before a high temperature is reached. On the contrary, those of higher molecular weight are hard to volatile until at high temperature, at which decomposition and cracking set in. From the present experiment it is clear that the Jurassic coals are rich in gamma compounds which do not help coking but give a higher yield of oil. The coals of Permo-Carboniferous age, like Nos. 369 and 373 etc., though containing much gamma compound yield less tar which show that the major portion of gamma compounds is left as cementing material.

In conclusion, the coking property of coal depends not only on the amount of gamma compounds but also on the nature and the decomposition products of these compounds. As this experiment shows, the coals of younger age though rich in gamma compounds are poorly coking, but that of older age, though less rich in gamma component, are good coking. So in the examination of coal the geological age, and the degree of coalification must be considered. As a matter of fact, they influence greatly the nature of gamma compounds.

#### 10. SUMMARY.

Sixteen bituminous coals collected from different districts in this country, were examined by means of solvent extraction. The results are, however, not very promising, if the amount of gamma component were taken alone as a criterion of coking properties. Since the coals are of different origin, age and degree of coalification, due consideration should be paid to these factors in the examination of coal by solvent extraction.

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# THERMAL TREATMENT OF THE PINGYANG ALUNITE

By

K. Y. KING\* AND C. C. HSIAO.\*\*

1. Introduction.
2. Previous Work.
3. Chemical Nature of Alunite Sample.
4. Effect of Temperature on Alunite Decomposition.
5. Extraction of Alum and  $K_2SO_4$  after Thermal Treatment.
6. Discussion of Results.
7. Acknowledgements.

## 1. INTRODUCTION

Alunite deposits along the south-eastern Coast of China were discovered about three hundred years ago. The total reserve and its potential possibility as a source of raw material for alum and potash industry were pointed out by Yih<sup>1</sup> when he published the results of his investigation of the geological nature of Pingyang deposit. Yih estimated the total reserve of Alunite to be 1,020,937,500 tons. Yet this figure is only limited to the coastal district of Chekiang; if other provinces nearby are included, the reserve will be still increased. The sole use of the ore so far has been for the manufacture of alum. The local practice<sup>2</sup> is to roast the stone in kilns and to leach out the alum in water. The maximum yield from the purest ore is only 25%. For average samples the yield is considerably less. Attempt to determine the mechanism of the roasting process with the objects of increasing the efficiency of alum production and of effecting a more profitable utilization of the alumstone constitute the purpose of this investigation.

## 2. PREVIOUS WORK

Potash alum has been extracted from alunite as early as the thirteenth century at Tolfa, Italy.<sup>3</sup> At Ballah Delah<sup>4</sup>, Australia, the mineral was calcined in reverberatory furnaces and treated with a weak solution of sulfuric acid. Guyot<sup>5</sup> recommended the addition of sulfuric acid and potassium sulfate after igniting the alunite at 800°C for three hours. He claimed that the total yield of alum was about 2.3 times the original weight of the ore. Schwartz, however, suggested that the best temperature for roasting was 500°C.

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\* Chief chemist of the National Geological Survey of China, Peiping.

\*\* Research fellow of the China Foundation for the promotion of Culture and Education.

The direct recovery of potassium sulfate from alunite was proposed by Wag-gaman<sup>6</sup>. During the World War, potassium sulfate was commercially extracted from alunite in America in the vicinity of Marysville, Utah, where the largest deposits in the United States are located. The mineral was heated at about 1,000°C to produce alumina and water-soluble potassium sulfate.

A number of methods proposed for the production of pure alumina have been described by Edwards<sup>7</sup>, Frary, and Jeffies. Most of the methods involved a preliminary roasting treatment to increase the rate of solution in acid. The temperatures suggested can be classified into three groups—500-750°C, 750-1,000°C, 1,000-1,600°C. In the first range, acid-soluble sulfates were probably formed; in the second,  $Al_2O_3$  and  $K_2SO_4$ ; and in the third either alumina and  $K_2SO_4$  vapor or potassium aluminate. Fink<sup>8</sup>, Van Horn, and Pazour verified this decomposition by X-ray diffraction methods. They showed that by heating at 500-600°C alunite was transformed into submicroscopic crystallites of dehydrated alum which decomposed into corundum and  $K_2SO_4$  at 700-800°C. At 1,200-1,400°C,  $K_4O \cdot 10Al_2O_3$  was synthesized.

Ogburn<sup>9</sup> and Stere observed two stages of the thermal decomposition of alunite. Combined water was liberated at 460°C, while complete decomposition of aluminum sulfate to alumina resulted at 800°C.  $K_2SO_4$  was not affected at the latter temperature, and was recovered as such.

Table I  
CHEMICAL ANALYSIS OF PINGYANG ALUNITE SAMPLE

Samples	Hsihua	Hsihua 5	Hsihua E <sub>2</sub>	Taihu	Tahua
*H <sub>2</sub> O—	.14%	0.30%	0.24%	0.18%	0.23%
*H <sub>2</sub> O+	10.00 ..	13.80 ..	12.86 ..	6.95 ..	9.90 ..
SiO <sub>2</sub>	18.00 ..	1.52 ..	8.30 ..	52.30 ..	27.22 ..
Al <sub>2</sub> O <sub>3</sub>	33.65 ..	38.24 ..	33.71 ..	19.09 ..	26.04 ..
Fe <sub>2</sub> O <sub>3</sub>	.57 ..	1.35 ..	1.99 ..	1.11 ..	3.83 ..
MgO	— ..	0.08 ..	0.08 ..	0.08 ..	— ..
CaO	.22 ..	0.84 ..	0.51 ..	0.30 ..	0.20 ..
K <sub>2</sub> O	8.64 ..	8.18 ..	8.60 ..	4.00 ..	6.63 ..
Na <sub>2</sub> O	.36 ..	0.22 ..	0.41 ..	0.90 ..	0.90 ..
SO <sub>3</sub>	28.86 ..	36.10 ..	33.83 ..	16.00 ..	25.73 ..
Total	100.44	100.63	100.53	100.91	100.68

\* H<sub>2</sub>O—refers to hygroscopic moisture.  
H<sub>2</sub>O+ refers to combined water.

## 3. CHEMICAL NATURE OF ALUNITE SAMPLE.

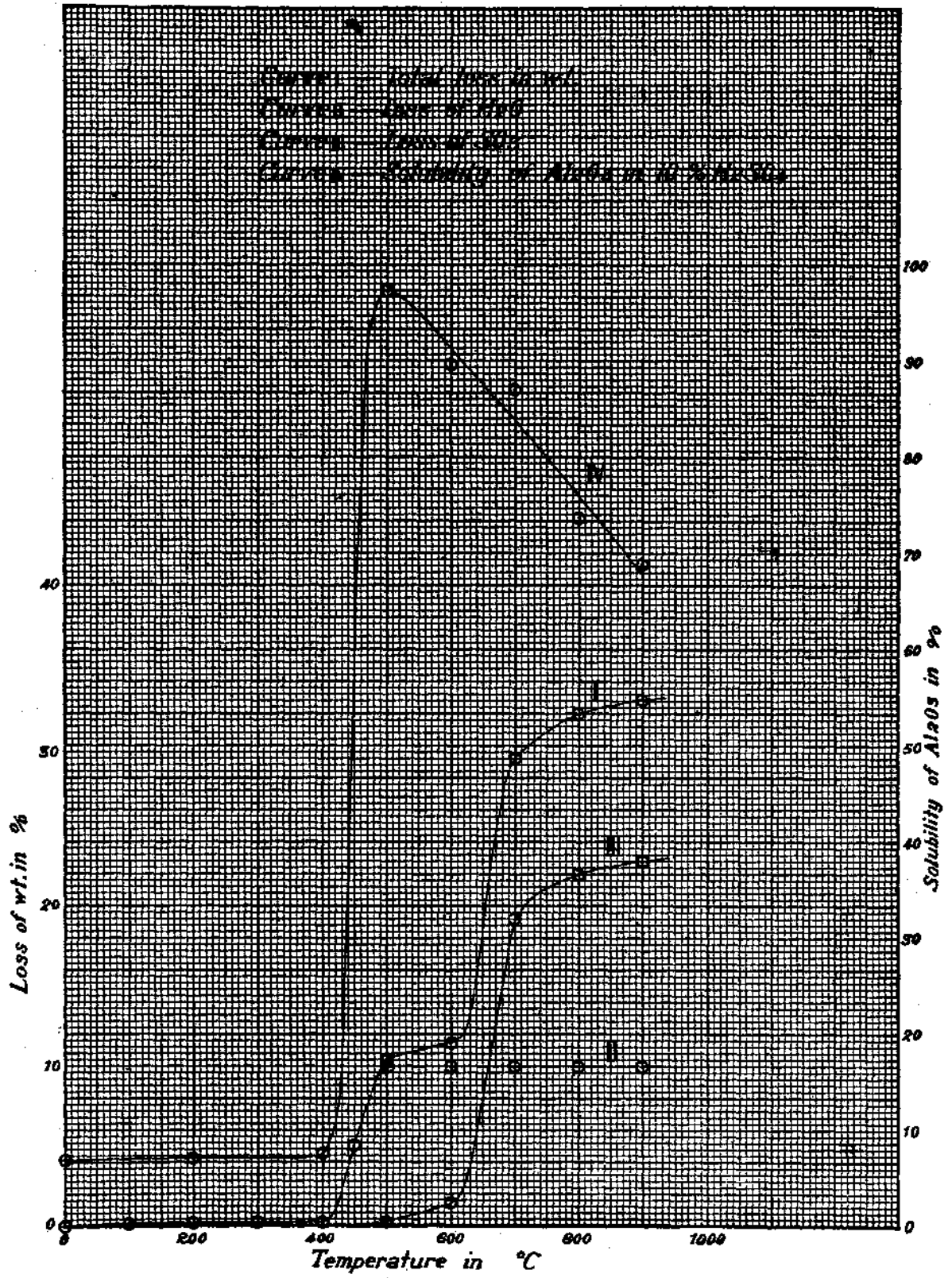
Four samples of alunite from Pingyang, Chekiang (locally known as Hsiahua (細花), Suntze (生子), Tahua (大花), and Hupan (虎斑) were received. The sample Hsiahua, having the smallest percentage of silica, was chosen for the experiment. Its chemical composition is shown in column 2, Table I. Columns 3, 4, 5 & 6 are analyses made by Li-huang<sup>1</sup> of the National Research Institute of Geology, Nanking on four type-specimens. The first sample is calculated to contain 74.70% of pure alunite (formula:  $K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$ ), the rest being kaolin (2.84%), free silica (16.68%), free alumina (4.93%) and other impurities as listed above.

## 4. EFFECT OF TEMPERATURE ON ALUNITE DECOMPOSITION.

To show the extent of decomposition at different temperature, three to five grams of the sample (ground to pass through a 40-mesh sieve) were weighed into a sillmanite boat which was placed in a silica tube inserted in an electrically heated tubular furnace. The temperature was controlled by an alumel-chromel thermocouple; and was raised 100°C for every new sample introduced. At regular intervals, the boat was removed from the furnace and weighed. After constant weight had been reached, the sample was analyzed for its  $SO_2$  content and the solubility of  $Al_2O_3$  in 10%  $H_2SO_4$  was determined. The results are tabulated below and are graphically represented in Figure 1:—

Table II  
ALUNITE DECOMPOSITION AT DIFFERENT TEMPERATURES

Temp. (°C)	Total loss of wt. (%)	Loss of $SO_2$ (%)	Loss of $H_2O$ (%)	Solubility of $Al_2O_3$ in 10% $H_2SO_4$	Duration of heating (hrs.)
not heated	0	0	0	7.00	0
100	.113	0	.113	—	10.75
200	.115	0	.115	7.20	10.25
300	.148	0	.148	—	8.00
400	.171	0	.171	7.51	12.50
450	2.57	0	2.57	—	25.25
450	5.13	0	5.13	—	60.00
500	10.32	.33	9.99	97.25	24.00
600	11.53	1.53	10.00	89.50	26.50
700	28.10	—	—	—	23.50
700	29.20	19.15	10.05	87.00	41.50
800	31.98	22.00	9.98	73.60	24.00
900	32.80	22.81	9.99	68.80	24.50



Two distinct stages of the decomposition of alunite are discernible. Up to 400°C the sample undergoes no intrinsic change other than the loss of hygroscopic moisture. The liberation of combined water begins at 450°C and rapidly goes to completion at 500°C. (indicated by the first steep portion of curve I) the complete removal of water is simultaneous with a sudden increase in solubility of the  $\text{Al}_2\text{O}_3$  content in acid. This is probably due to the formation of crystals of dehydrated alum as pointed out by Fink<sup>8</sup>, and is thought to be the best condition for producing alum. The second stage occurs at 700°C where aluminum sulfate decompose to a considerable extent as shown by the copious evolution of  $\text{SO}_3$ ,  $\text{K}_2\text{SO}_4$  is thus set free from corundum which, being insoluble, decreases the solubility of the sample by its presence.

Table III

RESULTS OF EXTRACTION AFTER THERMAL TREATMENT

Temperature	500°C		800°C
Loss of wt. after heating	20.0 gm. (10.0%)		61.8 gm. (30.9%)
Solvent used for extraction	$\text{H}_2\text{O}$	10% $\text{H}_2\text{SO}_4$	$\text{H}_2\text{O}$
Yield of alum	30.2 gm.	86.0 gm.	4.0 gm. (impure % $\text{Al}_2\text{O}_3=7.55$ )
Additional yield after adding $\text{K}_2\text{SO}_4$	—	40.1 gm.	—
Theoretical yield without adding $\text{K}_2\text{SO}_4$	171 gm.		—
% yield	17.65	50.30	—
m. p. of alum	90.7-91.5°C	90.5-91.2°C	—
Theoretical m. p.	92°C		—
Yield of $\text{K}_2\text{SO}_4$	—	—	30.6 gm.
Purity of $\text{K}_2\text{SO}_4$	—	—	92.9 %
Theoretical yield (calculated from $\text{K}_2\text{O}$ content)	—	—	32.0 gm.
% $\text{K}_2\text{SO}_4$ extracted	—	—	88.8
Residue after extraction	163.8 gm.	71.0 gm.	103.6 gm.
% $\text{Al}_2\text{O}_3$ in residue	39.10	27.14	61.78
wt. of $\text{Al}_2\text{O}_3$ in residue	64.00	19.25	64.00
wt. of $\text{Al}_2\text{O}_3$ in product	3.25	13.57	3.02
Total	67.25	32.82	67.02
wt. of $\text{Al}_2\text{O}_3$ in original sample	67.30	67.30	67.30
wt. of $\text{Al}_2\text{O}_3$ as $\text{Al}_2(\text{SO}_4)_3$ (By diff.)	—	34.48	—

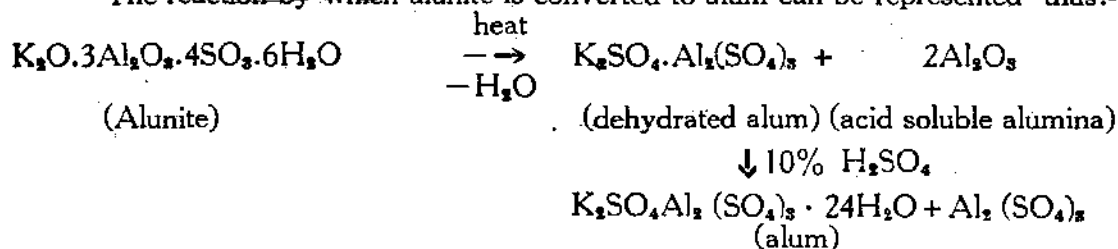
### 5. EXTRACTION OF ALUM AND $K_2SO_4$ AFTER THERMAL TREATMENT

To verify the above results, experiments on a comparatively larger scale at the two selected temperatures for the respective production of alum and potassium sulfate were considered necessary. In the latter case, 800°C was chosen instead of 700°C, because the decomposition of  $Al_2(SO_4)_3$  would be more complete and because the heating took much shorter time which, in practical experience would mean the economy of fuel. In each case, 200 grams of the same sample were placed in a muffle furnace for 24 hours (being average amount of time for each reaction to be complete). The heated mass was extracted for the product desired, and the results, together with an  $Al_2O_3$  balance, are shown in Table III.

The alum produced was quite pure as shown by its crystalline structure and the melting point tests. The slight impurity was due to the use of tap water for extraction. The  $K_2SO_4$  obtained evidently contained a slight amount of alum not yet decomposed by roasting.

### 6. DISCUSSION OF RESULTS

The reaction by which alunite is converted to alum can be represented thus:-



Just how the removal of water changes the nature of alunite is not known. It is probable that the water molecules hold up those of dehydrated alum and aluminum oxide in such a way as to form a hard and insoluble mass which decomposes only on heating. The slight solubility of dehydrated alum in water accounts for the poor yield in this experiment and also in local practice. The increase in yield by the use of acid medium is remarkable. If the effect of varying the acid strength is studied to determine the optimum concentration that should be used, the yield can possibly be improved to more than 50.3%. It is interesting to note from the aluminum balance that all the acid-soluble alumina are extracted though not all of the  $Al_2(SO_4)_3$  can form alum by the addition of  $K_2SO_4$ . This is probably due to the physical effect of concentration  $K_2SO_4$  and  $Al_2(SO_4)_3$  and the condition of alum crystallization, consequently a phase rule study should be investigated to clarify this point.



The direct extraction of  $K_2SO_4$  by heating at  $800^\circ C$  seems to be not economical unless use can be made of the evolved  $SO_2$  and the remaining  $Al_2O_3$ . Owing to the high percentage of  $SiO_2$  in the alunite sample, it is more advisable to recover the product in the form of alum and subsequently roast the alum to get  $K_2SO_4$  and  $Al_2O_3$  or precipitate the Al in form of  $Al(OH)_3$  by  $NH_3$  to obtain  $Al_2O_3$  and  $(NH_4)_2SO_4$ . The advantage lies in the ease with which alum can be purified and the consequent purity of the final products.

#### 7. ACKNOWLEDGEMENTS

The authors are indebted to Dr. L. F. Yih, Secretary of the National Research Institute of Geology, for supplying the samples for the experiment.

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# ON THE IRON ORE DEPOSIT OF BEIYIN OBO, SUIYUAN

By T. H. TING<sup>1</sup>

(SUMMARY)

1. Introduction.
2. Situation and Communication.
3. Stratigraphy.
4. Structural Geology.
5. Iron Ore Deposit.
6. Summary.

## I. INTRODUCTION.

Beiyin Obo is also called Beiyin Bogdo, which means in Mongolian language "Rich spirit", but the former name is more commonly used in that region owing to the attractive Obo. It has been regarded as the most powerful "Sacred Mountain" in Beile region.

While I was a member of the north section of the Sino-Swedish Expedition<sup>1</sup>, I had the occasion to climb up to the Beiyin Obo from our camp at Beiyin Bulak about 5 Kilometers south of the Obo, and fortunately I discovered a secret which is more profound than the religious belief and important for the geological science. This was the iron deposit which I am now going to describe.

The whole summit of Beiyin Obo was occupied by iron deposit which has an area of about 300,000 square meters in the main body. Scattered pockets of iron ore are also found in the surrounding rocks of limestone extending about 3 Kilometers to the east and west respectively from the principal body and ore sands resulted from weathering and erosion of the deposit also occur in several valleys.

I would take this opportunity to thank Dr. V. K. Ting, Prof. P. L. Yuan and Prof. C. Y. Hsieh and Mr. T. L. Ho for their valuable suggestions and criticisms.

## 2. SITUATION AND COMMUNICATION.

Beiyin Obo is in Beile region (貝勒地) about 100 li from Beile Miao (貝勒廟或百靈廟) and is bordered with eastern part of Momin An Djasak (茂明安旗) region; it is situated between two rivers: Chanhantologay Gol and Chananchelo Gol. It is about 400 li from Suiyuan and about 300 li from Paoto.

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1. Member of the Sino-Swedish North-west Expedition under the lead of Dr. Sven Hedin and Prof. P. C. Hsu.

The roads to that region are comparatively even, besides horses and camels, travelling may be even made on cart. Grass and streams are usually abundant in many places and villages and Mongol-tents may be found near the road.

There is an automobile road of 300 li between Suiyuan and Beile Miao, which takes only 5 hours to cover the whole trip. From Beile Miao to Beiyin Obo, it can be reached on horse back in 6 or 7 hours, so that the whole journey can be covered in one day, if no interruption occurred on road.

### 3. STRATIGRAPHY.

In Beiyin Obo the following formations are present:

*The Sinian:* This is composed of quartzite and limestone, shale and slate, the former occurs at the valley bottom of the eastern slopes, varying in colour from white to dark gray. It is the lowest part of this formation. Upon the quartzite is laid a series of massive metamorphosed siliceous limestone showing no clear bedding.

This limestone often forming high mountain is developed in the northern part of Beiyin Obo, its thickness judging from the elevation of the mountain is estimated at least 600 meters.

At the southern rock terraces, a series of slate and shale is found in fault contact with the siliceous limestone. It is intensely metamorphosed showing distinct schistosity. Under microscope many inclusions of yellowish opal and black carbonaceous substances are found, and in some specimens later filling of quartz in forms of veinlets are also seen. Lithologically this series bears close resemblances to the series of Amuser which lies concordantly upon the same limestone, therefore it is tentatively referred to this period.

*Quaternary and alluvium:* The latest sediment are composed of loess, sands and gravels occurring in the valleys and slopes.

*Igneous rock:* Along the south slope of the Obo mountain (Pl. I) there occurs a diorite which occupies an area of about 200 meters wide, in the form of a small laccolith. The mass is of dark greenish colour, holocrystalline and medium grained. Under microscope it is composed of albite, oligoclase and some hornblende. It cut through the series of limestone and slates which are metamorphosed. The age of the intrusion is post-Sinian, but it cannot be more exactly determined, owing to the absence of later sediments in that region.

Quartz veins are very common in that region, always forming salient points in the desert due to their resistance to weathering. They cut across the above mentioned rocks.

#### 4. STRUCTURAL GEOLOGY.

The range of Beiyin Obo is a part of the divide between Langshan and Gelobai, and is probably formed by the warping during post-Oligocene time. Structurally it forms a gentle anticline running NW-SE, with a series of close fold and a few faults; the northern limb of the anticline extends northeastward to go far as one can see from the Obo, while the southern limb is suddenly terminated by igneous rocks near the slope of the mountains.

Faults in Beiyin Obo may be referred to the diagonal type as they have cut the strata diagonally. One fault occurs along the south slope in the south limb of the main anticline, indicated by sudden change of strikes and dips of two different kinds of rocks. Another fault occurs in the northern broad valley, following more or less the course of a dry river and in which several quartz veins parallel to the river are also seen.

#### 5. IRON ORE DEPOSIT.

The iron ore deposits usually occur in veins and fillings in limestone forming irregular but distinctly bedded or banded masses. Beginning from the middle part of the north escarpment of the range the ore body curves down to the south slope where terminated by a fault so as to bring the deposit in contact with the upper slate. Both western and eastern parts of strata were eroded away, so that the foot wall of the ore formed a roof of the range.

Basing on a few field observations, it is concluded that the ore body could not be terminated suddenly and might extend downward further than its exposure, but the actual depth cannot be ascertained unless by drilling.

Several minor iron deposits are also found on the north side, just in the center of the northern anticline; they have the same characteristics as the main deposit, but they are too scattered to be of any economic importance.

The iron ore was deposited as a result of the action of gas and hydrothermal solution emanated from the dioritic magma connected with the iron deposits.

This conclusion is based upon the following facts from field observations as well as from laboratory study.

1. The ore is not directly in contact with the diorite or other igneous rocks, though they are very close together.
2. The ore is composed principally of hematite, specularite, pyrite, limonite and magnetite, the last one is always associated with fluorite and quartz, and sometimes with epidote, and diopside indicating that a part of the ore was formed under high temperature.
3. The alteration of the country rocks has been very extensive, large part of limestone changed into a kind of hard, porous and sometimes chalcedony-like mass, and its intensity becomes stronger near the ore than away from it. In colour the altered rock varies from gray to dark brown according to different content of iron. Under microscope, it is composed largely of calcite, quartz, barite and fluorite with little amount of epidote, diopside and some iron ore.

The phenomena of replacement are distinctly shown in the thin sections of the rock, thus calcite has been replaced by fluorite, hematite, specularite or limonite and still preserving some characteristics of original mineral. All these features proved that metasomatic process is very extensive in that region.

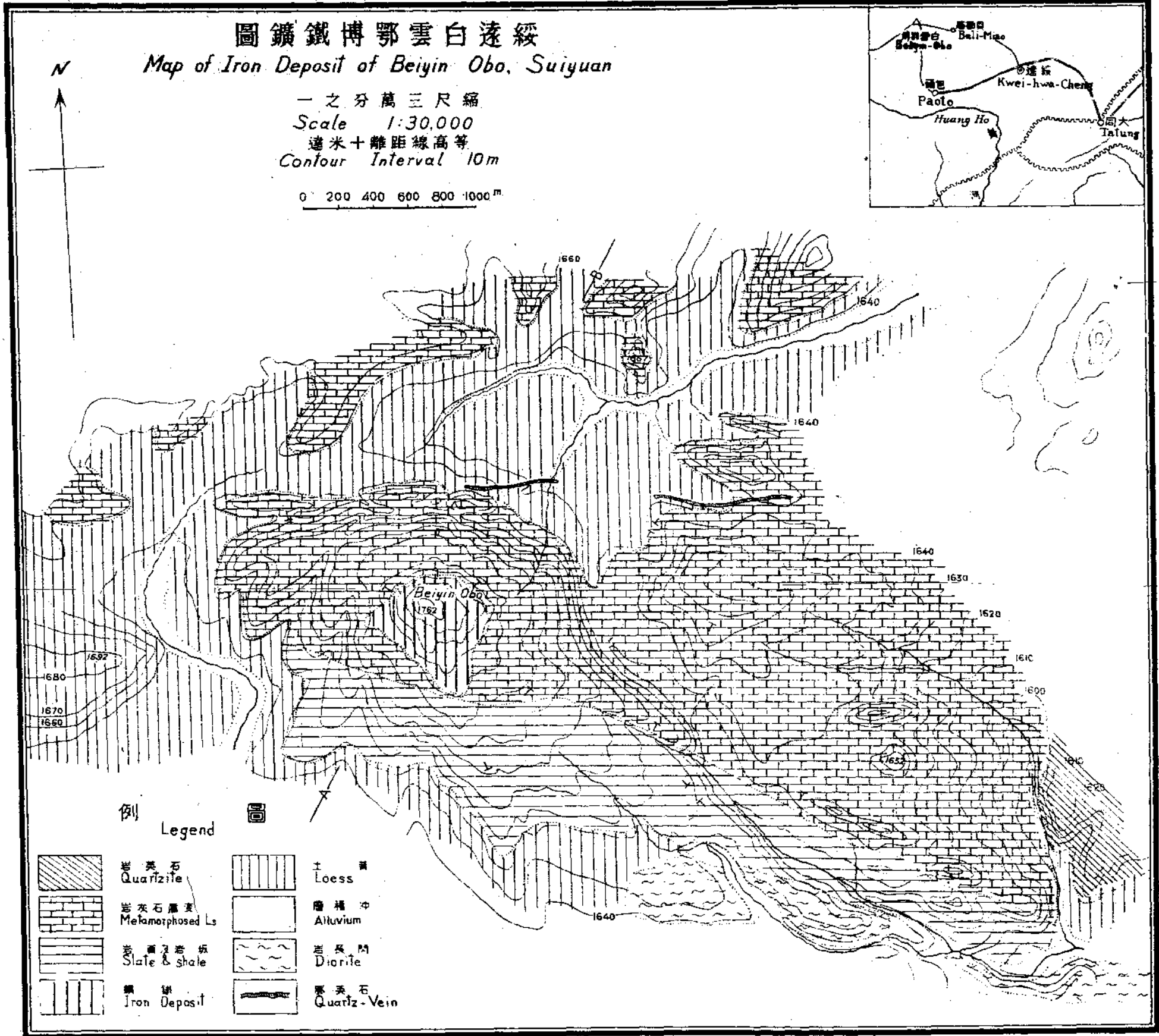
4. The cavities of the altered limestone are filled up by agate showing a typical and beautiful structure under microscope.
5. The rocks are certainly metamorphosed and much altered, but no minerals of contact zone such as garnet have been found.

#### 6. SUMMARY

To compare the ore with other iron deposits of China, it is closely similar to that of Liuhsiang, Southeastern Hupeh<sup>2</sup> and that of Tawashan and Nanshan, southern Anhui<sup>3</sup>

In type and genesis, these three localities strongly resemble one another.

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**Explanation of**  
**Plate II.**

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## PLATE II

A. Diorite:

Plagioclase (Pl) and common hornblende (H) showing cleavage lines.  
Cross nicol,  $\times 40$ . South range of Obo.

B. Epidote rock:

Prismatic crystals of Epidote (a), diopside & biotite flakes (J), Fluorite (Fl).  $\times 100$ . Western cliff of Obo.

C. Iron Ore:

Magnetite and hematite (black) associated with fluorite (Fl), barite (T). East side of Obo.

D. Iron Ore:

Magnetite, hematite, fluorite (Fl) and quartz (Qu) inter-grown together.  
Cross nicol,  $\times 40$ . East side of Obo.



a



b



c



d