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

第二十六號

民國二十四年九月

總目

北平西城兵馬司九號地質調查所圖書館發行

實業部直轄地質調查所組織條例

（民國二十一年七月十八日國民政府公布 二十四年五月二十八日國民政府修正）

第一條 實業部直轄地質調查所所掌事務如左

一、關於調查全國地質及測量地質圖事項

二、關於全國礦山測量礦床研究礦業統計及其他礦產調查事項

三、關於調查全國土宜及水力水利之研究事項

四、關於關係地質之實業設計及研究事項

五、關於地震之測候及研究事項

第二條 地質調查所設左列各館室

一、圖書館

二、地質礦產陳列館

三、燃料研究室內附礦物岩石研究室化學試驗室古植物學研究室及照像室

四、土壤研究室

五、古生物學研究室

六、地性探礦研究室

七、地震研究室

第三條 地質調查所置所長一人簡任技正十二人荐任技士十六人至十八人荐任或委任技佐十二人至

十六人事務主任一人事務員二人至四人圖書館陳列館主任各一人委任

各研究室或試驗室主任得由所長指定技正或技士兼任之

第四條　所長承實業部部長之命綜理全所事務監督指揮所屬職員

第五條　各館室主任承所長之命分掌各該館室事務

第六條　技正技士技佐承長官之命分任調查研究編輯測繪化驗各事務

第七條　事務主任事務員承長官之命辦理文牘庶務會計各事務

第八條　地質調查所得酌用練習員四人至八人書記二人至四人

第九條　地質調查所得隨時派員往各省實地調查測量或採集關於地質研究資料

第十條　地質調查所對於政府機關之咨詢或請託調查事項應儘先辦理並得應實業團體之請求派員代任地質問題之調查或研究

第十一條　地質調查所得派員往外國研究考察或參加國際學術或技術會議但應先行呈請實業部核准

第十二條　地質調查所關於學術研究事項得商承國立中央研究院及北平研究院隨時合作辦理

第十三條　地質調查所對於各省地質調查機關之工作應隨時協助考察並規劃全國地質調查進行辦法呈報實業部

第十四條　地質調查所辦事細則由實業部定之

第十五條　本條例自公布日施行

地質彙報第二十六號目次

安徽廬江礬石礦地質研究

程裕祺　陳愷

第一節　導言

二十二年十月初旬，作者等隨同謝家榮先生，調查江西城門山鐵礦既畢，卽奉命赴廬江勘看礬石礦。實地調查時間共八日，地形測量及地質觀察，各佔其半，自測縮尺二萬分之一地形地質圖一張，東西長七公里許，南北長約六公里，凡產礬石之地點，皆已包括在內。

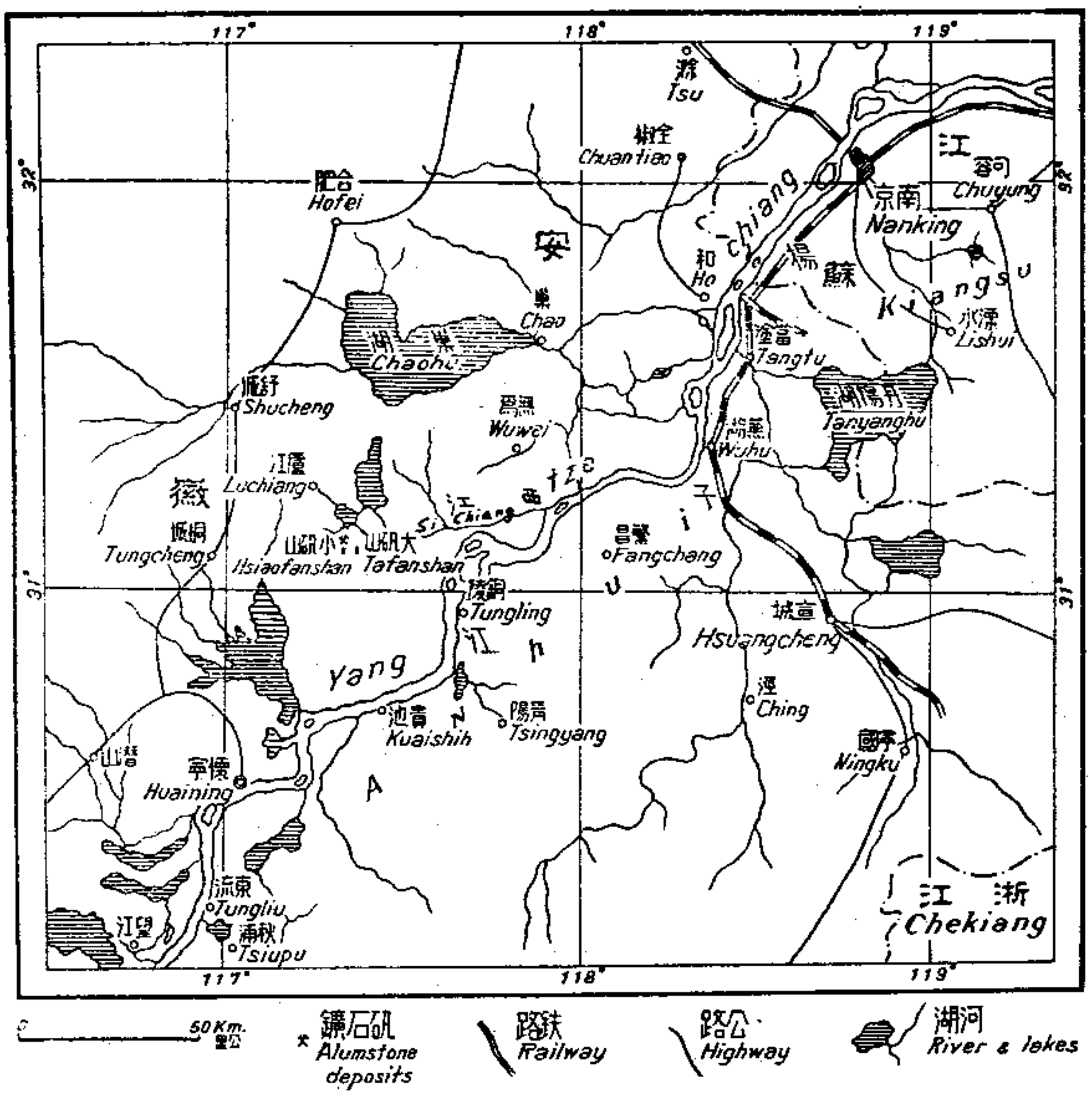
按我國礬石重要產地有三，卽浙江平陽，安徽廬江及福建福鼎。平陽之礦，有葉良輔張更二君調查在先，並已著有專門報告（一），最近復經愷之勘查，其蘊藏數量雖不及葉張二先生初勘之富，然爲數極多，尤推全國之首位。至廬江之礦，經此次調查後，纔知其礦量遠較平陽爲少，然亦尚稱豐富，如能善自利用開發，亦未始非吾國大富源之一也。

礬石礦之顯微鏡研究，承謝家榮先生加以指示，始得有相當之結果；又一切化學分析，皆由本所化學試驗室熊尚元先生担任，其結果于礦量之估計，大有補助；並書之以表謝忱。

(附註　本區之侵入岩，多由陳君鑒定。礦石之比重，乃陳君與鄙人共同測定。其他各部之研究及報告之編製，均由祺担任，因陳君遠適雲南，未及徵求其同意，如有錯誤之處，皆祺一人之責任。　程裕祺謹識)

第二節　交通及地形

廬江礬石 (Alumstone or alunite-rock) 礦在縣城東南四十餘里(附圖一)，西南距安慶約一百五十里。含有明礬石(Alunite)之岩層，分佈甚廣，東起石曹嶺(第一版)，西止觀音頂，北自鑫山，南迄夏家院子，凡此縱橫約各五里之面積內，無論其爲噴出岩或侵入岩，殆皆有其縱跡；然蘊含甚富而能開採以鍊明礬者，卽礬石礦，僅數薄層而已。大小礬山街二鎮，卽位于礬石礦之旁，開礦之人及鍊礬窰戶(第四版第三圖)，皆居于是焉。



第一圖　示廬江礬石礦之位置

所產之明礬，裝于竹簍內，先由工人挑至大礬山北十五里之缺口鎮，然後轉裝小舟內，沿西江上溯，運至縣城及附近諸地，或順江下行，入于長江，水程凡二百餘里而至蕪湖。由此用大貨船或汽船駁載，運銷沿江各埠。西江水道尚深，較小之船，可以終年通航，除冬季外，並可航行吃水五六尺之小汽船，故明礬之運銷，尚稱方便。亦有少數明礬，用人力挑至小礬山西三十五里之羅昌河，再由民船運至附近各地。

大致言之，礦區居于一壯年山地之邊際，谷廣坡緩，山頂平圓，交通方便。但在畢家老之東，則曾見此壯年地形，復爲一少年期峽谷所割切，造成此種河谷之下蝕作用，至今猶在進行中。壯年山形之生成，或在第三紀之中期，遠在花崗閃長岩侵入之後。

山頂之高度，多高出附近平地二百公尺以上，最高者爲鍾子山，達三百五十餘公尺。本區內地層所受之變動甚小，大致均向西或西北傾斜，以是地形甚爲齊整，而傾斜坡面 (Dip slope) 及蝕餘懸崖 (Hog-back)，亦數見不鮮。河道以順向谷及後成谷爲主，多相互直交，構成方格形水系 (Trelliss drainage)。火山岩及石英岩之走向約差四十度，故二者所造成之山脊亦各相斜交，試展地形圖視之，卽一目瞭然。

因造山岩層，其性質不盡相同，故區內各山之形態，亦有微小差別。鍾子山系之石英岩，質密性堅，不易侵蝕，皆成高山—高出平地三百公尺以上—其形勢亦較峻拔（第三版第四圖）。火山岩較易風化，多成小山，然曾被矽化者，其質亦堅，山頂高度可達二百六十公尺。侵入岩更易風化，常破碎而爲粗粒泥砂，圓邱低岡，皆由此組成。

第三節　地層及構造

本區之地層及構造，皆甚簡單。最老地層，爲侏羅紀之鍾山層，厚約七百公尺，不整合于其上者，乃白堊紀之火山岩系，厚一千五百公尺；二者皆僅受和緩之褶曲或拗曲作用之變動而已。復上卽爲冲積層。因未覓得化石，與附近各地作地層比較，實甚困難。今自下而上，分述如左：

甲、鍾子山層

在礦區之東南，石英岩之露頭甚多，山形較峻，其頂部之高度，達三百公尺以上；如鍾子山及天光山是。此種岩石，色白質堅，驟視之，有時與火山岩系中之灰白色矽化細凝灰岩，甚難分別，但後者多細小氣孔，而前者無之。此種岩層，似可與南京鍾山之紫霞洞石英岩層（二），及當塗采石層上部（三）相比擬，其理由申述于後：

（一）其岩石性質與上述二層極相近似。

（二）白堊紀火山岩系不整合遞積于其上部，此與采石層之情形相同。白堊紀火山岩之前，有一極大之整合，與之接觸者，其時代固不僅限于侏羅紀，然既無確實證據知爲較老之地層，不如歸入侏羅紀，較爲近似。

（三）據最近之調查，南京蕪湖間有一略近東西向之向斜層（四），二翼多由采石系組成。今本層大致向北緩傾，大致與此大向斜層之南翼遙遙相接，則采石層之上部，固可向西延長，而至是處。故其時代亦爲侏羅紀。然礬山距離南京既有四百餘里，距當塗亦近三百里，而又乏化石證據，若全憑岩性之比較而賜以同名，究屬不妥，故另立一新名焉。

乙、白堊紀火山岩系

火山岩系不整合于石英岩之上，大致均向西傾，在調查區域內分佈極廣。據其岩石性質噴發程序，可與浙江之建德系（五），浙贛閩三省交界之武彝系（六）及南京（七）當塗（八）之火山岩系相當，屬上白堊紀。

岩石之種類甚多，計有安山岩，安山凝灰岩，粗面岩，粗面凝灰岩，火山角礫岩，細凝灰岩及凝灰砂岩等，亦偶有近似流紋岩者，惟以所受之熱液變質故，致未能準確檢定。除安山岩外，大致均作灰白色。其表面受潛水及大氣之侵風化頗盛，即其內部，爲上升熱液所變蝕，亦多失其原來之狀態。各種岩石所呈之變蝕程度，並不一律，此與其本來之成分及組織有關。業已矽化者，質較堅硬，其他則以久經變蝕，故組織反趨疏鬆。在轎子頂，有一部岩，受溶液之鐵化作用影響，已變爲劣質鐵礦。此種熱液變蝕作用，與本區之酸性侵入岩有密切關係，後當詳論。

本系之露頭尚未完全，欲作一完美之柱狀剖面圖，實不可能；據野外觀察及標本之研究，自上而下，其大致層序當如左列所示（參閱第二版）：

（二十四）灰白色粗面凝灰岩及粗面斑岩（頂部未露出）厚八十公尺。

（二十三）灰白及紫白色塊集岩及火山角礫岩，有時略呈礬化及矽化，五十至六十公尺。

（二十二）灰白色凝灰岩，粗面凝灰岩及粗面岩等，局部業已礬化及矽化，然所含之明礬石甚少。五十六十公尺。

（二十一）雜色礬石層，乃含明礬石甚多之凝灰岩及粗面岩等（第六礬石層）零至四十公尺。

（二十）紫白二色相間之層狀粗面岩，流紋狀構造極爲清晰，略呈礬化；或爲含石英極少之流紋岩。五至十公尺

（十九）白色矽化凝灰岩，質堅，但有小氣孔。八十至九十公尺。

（十八）紫白色塊集岩，有時略呈礬化及矽化。約十五公尺。

（十七）礬化及矽化之凝灰岩，粗面凝灰岩及粗面岩，外表作灰白或紫白色，但所含之明礬石甚少。約六十公尺。

（十六）礬石層，乃一礬化甚深之粗面斑岩。（第五礬石層）零至五公尺。

（十五）灰白色礬化及矽化之凝灰岩及粗面岩等。約一百公尺。

（十四）礬石層，乃白色及灰白色之礬化粗面凝灰岩及凝灰岩，有時含矽質甚高。零至八公尺。

（十三）灰白色礬化及矽化之凝灰岩及粗面岩等，所含之明礬極少。厚約一百公尺。

（十二）紫白及灰白色相間之層狀凝灰砂岩，略呈礬化，組織鬆散。約四十公尺。

（十一）灰白色礬化及矽化之凝灰岩及粗面凝灰岩等。三十公尺。

（十）礬石層，乃雜色之礬化細凝灰岩，火山角礫岩，粗面岩及粗面凝灰岩等，有時含矽質甚豐。（第三礬石層）三十至五十公尺。

（九）礬化凝灰岩及粗面凝灰岩。一百公尺。

（八）紫色及灰白色凝灰砂岩，略呈礬化。四十公尺。

（七）礬石層，乃一礬化之凝灰岩及凝灰砂岩。零至五公尺。

（六）紫色及灰白色凝灰砂岩，略呈礬化，厚約四十公尺。

（五）白色矽化凝灰岩，偶呈礬化，質堅密，但有細氣孔極多。厚四十公尺。

（四）礬石層，乃礬化之粗面凝灰岩及塊集岩等。（第一礬石層）零至十公尺。

(三)白色矽化凝灰岩，與(五)相似。二百二十公尺。

(二)粗面凝灰岩及粗面斑岩，變蝕甚深，一百公尺。

(一)安山凝灰岩及安山斑岩厚三百公尺。

全系共厚約一千五百五十公尺，但其頂部尚未露出。

在上表中。(一)(二)二層露出于潘石嶺盧家凹間；(三)至(八)露出于東山，向南沿長至于石曹嶺之西；(九)至(十四)層見于大磐山街及轎子頂間；(十五)至(二十一)層露出于小磐山街及轎子頂間；自(二十二)層以迄頂部，則于小磐山以西見之。本系之上部，是否有走向斷層之存在，致使地層重複，尚屬疑問；如能詳細工作，則此問題不難迎刃而解也。

如上表所示，全系岩石之成分，并不一列，大致底部者性近鹽基，上部者趨于酸性；此種噴發之程序，與我國沿海各地白堊紀火山岩系之岩層層序，大致相合。以此爲準，可分爲上下二部，上部岩石以細凝灰岩，粗面凝灰岩，粗面岩及凝灰砂岩爲主，厚一千二百五十公尺；下部由安山岩及安山凝灰岩組合而成，厚三百公尺。然此種分法，在地層學上之意義甚小，蓋二者之間，並未有侵蝕之間斷也。上部岩層內之凝灰砂岩，是否表示火山岩之噴發曾暫時停止，而爲正常之侵蝕及沉積作用所代替，尚未敢斷言。

火山岩標本及薄片之詳細描寫，載英文篇中，此處從略。

丙、冲積層

山地之邊際及山谷之間，有冲積層。其成分，亦略有變異；平地中以黃色粘土爲主，農耕最宜；山麓者則爲壤土或砂土，且有礫石相互成層，

丁、構造

本層之地層構造，極爲簡單，僅有平緩之褶曲或拗曲，斷層則尚未之見。石英岩層大致構成一背斜層　，其褶軸在天光山之

南，約作東東北西西南方向，傾斜角則在三十度以下。火山岩系向西或南偏西七十度傾斜，傾角自十度至六十度不等，但以十五度至三十度爲普通。侵入岩之體積過小，故于地層構造，無顯殊之影響；卜家嶺東閃長岩之位于背斜軸中心者，乃爲巧遇，蓋其侵入時，背斜之勢固早已形成矣。如以全區爲單位，則居于一大向斜層之南翼，且似與甯蕪向斜層（九）遙相連接。今將此簡單之地動史實列表如左；

(一)侏羅紀後白堊紀前之褶曲運動—其軸向爲東東北西西南

(二)白堊紀後(第四紀前？)之褶曲或撓曲運動—其軸向近于南北。

第四節　侵入岩

侵入岩共有三種，即顯微花崗岩，斑狀正長岩及閃長斑岩是也。從野外觀察及理論上之推想，當知此三種岩石，乃自同一岩漿分化而成。董家嶺龜山間之花崗岩體，實爲侵入岩之中心，其中部爲顯微花崗岩，四週已變爲正長岩，並略呈斑狀。露出于查屯凹者，亦爲斑狀正長岩，蓋離此岩漿之中心，已有相當距離之故；至閃長斑岩，其露頭愈遠，成分更趨鹽基性，斑狀組織亦愈明顯。故礦物組織及岩石成分之隨距離岩漿中心點之遠近而逐漸變化，至爲明顯，而分化現象，亦得以証明非訛。

顯微花崗岩之外表作肉紅色，其成分以正長石及鈉長石爲主，並有少量之石英，角閃石及黑雲母等，礦物之體積甚小，普通其長度均在一粍以下，組織細密，在顯微鏡下，呈花崗岩狀。此外尚偶有少數白色斜石斑晶，生于此種全晶質之基質內，最長者達六粍。在採集之標本內，亦有包含微量之黃鐵礦細粒者。

斑狀正長岩亦呈肉紅色，斑晶爲白色之酸性斜長石及肉紅色之正長石，其量遠較基質爲少，後者之礦物成分與花崗岩內者相似，惟無石英，角閃石特多，而體積較小。亦有含多量之鈉長石而其成分已近二長岩者。

閃長斑岩多成不規則之小侵入體，露出于轎子頂南，石曹嶺，鍾山園子，潘石嶺，鍾子山南，羊山之東及卜家嶺等處。其外表作棕藍或棕灰色，斑狀組織極爲明顯，斑晶及基質之量大約相等，有時前者略少。斑晶以鈉鈣長石及中性長石爲主，角閃石及

普通輝石次之，亦有少量之磁鐵礦，燐灰石及鋯英石。基質仍爲全晶質，含有斜長石，角閃石，輝石及磁鐵礦等。

因其體積過小，而後來之熱液變蝕作用又特爲顯殊，故侵入岩之接觸變質作用，不易追搜，鍾子山層內石英層之造成，是否與之有關，尙屬疑問。其本身，則往往復受上升熱液之影響，變蝕甚深，但離礬石層較遠者，則尙新鮮，原來之組織及成分，亦能大部保存。關于此種變蝕作用所發生之影響，當于第六節中論之。至其侵入時期，甚難確定，大致爲中生代之末，或第三紀之初，各種岩石之詳細敘述，見英文篇中，此處從略。

第五節　礬石礦

甲、野外觀察

本區內含明礬石最富之礬石，乃採自大礬山西珠寶坑（參閱第二圖，又第三版之，4）採礦塲之P層（第四圖），外表作灰白色，組織細密，斷面平滑，呈半介殼狀，因含矽甚多，質極堅硬，驟視之，與華北震旦紀之灰白色矽質灰岩，極爲相似。據化學分析，含鉀明礬石達百分之五三·二九，在顯微鏡下視察之，幾完全由小鱗片狀明礬石石英微粒所組成，前者約佔總面積三分之二。

含明礬石較少之礬石，普通亦爲灰白色，亦或偶呈紫色，然半介殼狀之斷面，則從未見及。因其原來礦物成分及組織之各異，所受礬化及矽化作用之影響不同，故其外表及岩性亦互有差別，難以歸納得一普遍之特性。有組織粗鬆而似凝灰岩者，有質均性堅而類石英岩者，有斑狀組織極明顯者，有組織細密而具有多量細氣孔者，亦有少數岩石，質甚堅密，含有明礬石之結晶，肉眼視之，亦甚清晰。

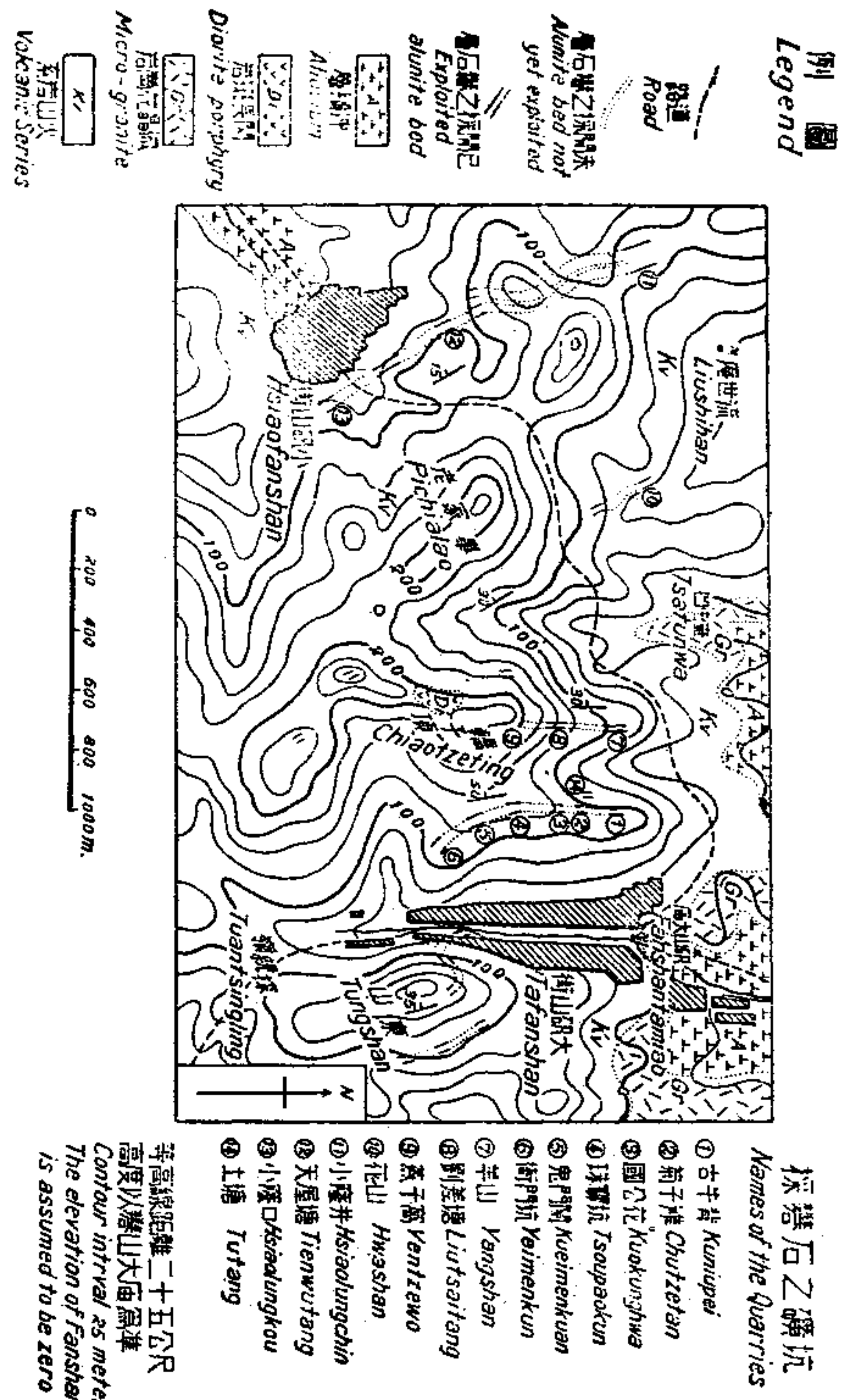
在此分佈寬廣之礬化火山岩內，足以開採之重要礬石凡六，今自下而上（自東而西）分述如左（參閱第二圖）：

（一）第一層露出于東山（第三版第三圖）之東坡，乃一礬化甚深之凝灰岩，其下爲灰白色之矽化細凝灰岩，其上先有一薄層礬化塊集岩，復繼以灰色及灰紫色之細凝灰岩。全層厚約四公尺，長三百二十公尺，向西西南傾斜，傾角約四十度。現有本地居民

開採。

（二）第二層乃一礬化凝灰砂岩，露出于東山之頂及其西坡，位于第一層之上，厚一二公尺，長一百五十公尺。前曾開採，現已暫時停工。

（三）第三層見于大礬山街西之坡面及山脊上，乃由礬化及矽化之細凝灰岩，粗面凝灰岩，粗面岩及火山角礫岩等所組成，上下皆爲略呈礬化之雜色凝灰岩及粗面凝灰岩。全層厚五十餘公尺，礦質最佳者厚九公尺至十公尺半，長七百餘公尺，層面向西或西西南傾斜，斜角自四十至八十度不等。大礬山附近之有名採礦場如土塘，古牛背，菊子灘，國公花，珠寶坑（第三版第三圖），鬼門關及衙門坑（第二圖）七處，皆沿其層向而開採者。現在開工者，爲國公花



第二圖　示廬江礬石礦之分佈

及珠寳坑二處。

（四）第四層由礬化甚深之凝灰岩及粗面凝灰岩合組而成，上下皆爲灰白色礬化甚淺之凝灰岩，露出于轎子頂北，以迄羊山。全層厚八至十公尺，長五百公尺，大致向西或南偏西八十度傾斜，傾角約三十度上下。羊山，劉差塘及燕子窩三坑，皆開掘此層之礦石，惟多巳停工。

（五）第五層乃一礬化粗面岩，露出于花山附近，厚一公尺半，長三百公尺，向西南或南西六十度作三十五度之傾斜，曾有三四小採礦塲開採之。轎子頂南舊採礦塲內之礬層，如係由此向東南延長而來，則其長度可增加不少。

（六）第六層係由二厚度相等之礬岩層合併而成，一長六百公尺，一長一千二百公尺，其岩石性質與第三層相似。全層厚自三十至六十公尺不等，較佳之礦則厚僅五六公尺（平均數），向南西六十至八十度傾斜，傾角約十五度至三十五度，但以二十度以下者爲普遍。小礬山街附近之有名採礦場如小饢口，天屋塘（第四版第一圖）及小饢井等三處，皆開掘本層之礬石。此外新興之小採礦塲甚多。

除上述六大層以外，曾經本地居民開採之小礦層尚多，因無關重要，故暫從略，又據顯微鏡下研究之結果，石曹嶺北六百公尺處之礬化及矽化之細凝灰岩，及夏家院子北三百公尺處之礬化及矽化之粗面斑岩，皆含明礬石甚多，約有百分之三十以上，或能用以鍊礬。故如在本區內，復作詳細之調查，則新礦層之發現，非不可能，若然，則于國計民生皆大有裨益。

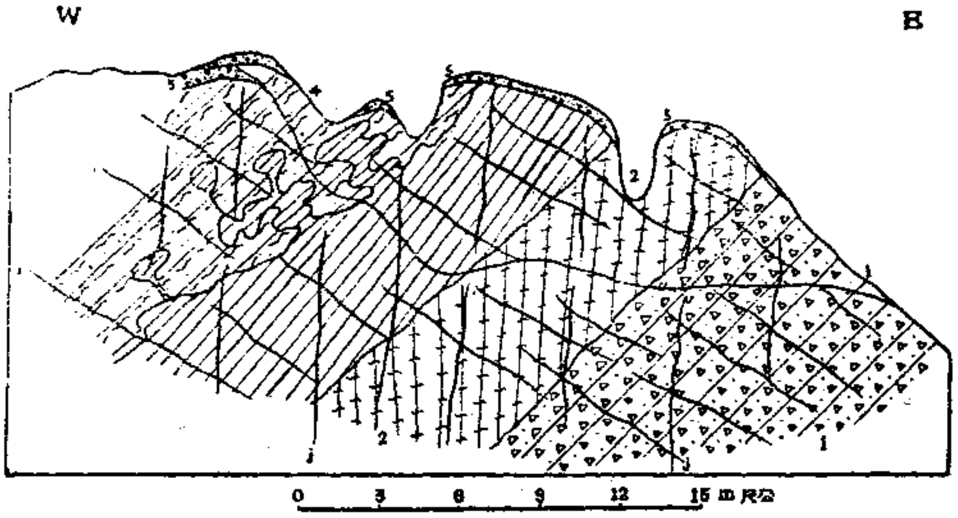
上述之六礬石層，皆爲礬化甚深之火山岩，其厚度並不如水成岩之一律，僅大致成層狀而已，有時可逐漸變薄，以至于無，亦有特別加厚而略成袋形者。今分述二剖面圖于後，以明其產狀及礬化時發生變換作用之眞相。

第三圖示羊山採礦場礬石層之情形，其上下界線極不規則，尤以上部最爲紛亂，蓋以圍岩性鬆易爲溶體滲透之故。此種不規則之接觸情形，實爲代換作用之特徵。

第四圖乃大礬山西珠寳坑採礦塲之剖面圖，今將各層之名稱厚度及成分，自上而下，依次分述如左：

圖中之記號	岩石號數	岩石名稱及性質	厚　度	明礬石成分（顯微鏡下估定或大致估計）
a		灰白色矽化凝灰岩，略呈礬化	五公尺	20%以下
b	R.No.5949	灰白色礬化及矽化之凝灰岩	二公尺	約40%
c		紫灰色凝灰岩略呈礬化	三公尺	20%以下
d	R.No.4960	白色及紫白色之礬化凝灰岩	二公尺	約40%
e		白色礬化及矽化之凝灰岩	十八公尺	30%以下
f	R.No.4965	灰白色矽化凝灰岩，略呈礬化，含有片狀明礬石結晶體	〇·六公尺	10%以下
g	R.No.4964	白色礬化及矽化之凝灰岩，含有針狀明礬石結晶體	〇·九公尺	約30%
h	R.No.4972	灰白色礬化甚深之粗面凝灰岩，呈流紋構造	一·五公尺	約50%
i	No.4971	灰白色礬化及矽化之粗面岩	一·五公尺	30以上
j	R.No.4970	紫白色礬化粗面斑岩	二公尺	約40%
k	R.No.4968	紫白色礬化及矽化之凝灰岩	四公尺	約40%
l	R.No.4968	紫白色礬化及矽化之粗面凝灰岩	一·二至二公尺	50%以下
m	R.No.4963	灰白色矽化及礬化之粗面凝灰岩	〇至一·一五公尺	約30%
n	R.No.4969	灰白色礬化及矽化之細凝灰岩	一·三至二公尺	約50%
o	R.No.4967	灰白色礬化及矽化之火山角礫岩	一·二公尺	約40%
p	R.No.4961	紫色及灰白色礬化甚深之細凝灰岩，略呈矽化。	五公尺餘	約60%

灰白色礬化及矽化之凝灰岩（大部爲岩石碎塊所掩覆）	十公尺	約40%
紫白色礬化及矽化之火山角礫岩或塊集岩	五公尺以上	約40%



第一圖　羊山礬石礦在火山岩系中生成情形

如圖所示，有二點堪令吾人注意：卽（一）礬石層之界線，尙屬整齊（二）在極短之距離內，明礬石成分相差甚大。據合理之推測，若各岩層之組織較密，不易爲溶液所滲透，而溶液之上升，又甚遲緩，則因交換作用造成之礬石層，其上下界線，當較齊整。至岩層岩性之各異，及熱液上升時各處礬化之深淺不同，實爲造成各層內明礬石貧富不均之主因。是可知明礬石之富集于某層，並非出於偶然之機遇也。

乙、標本之研究

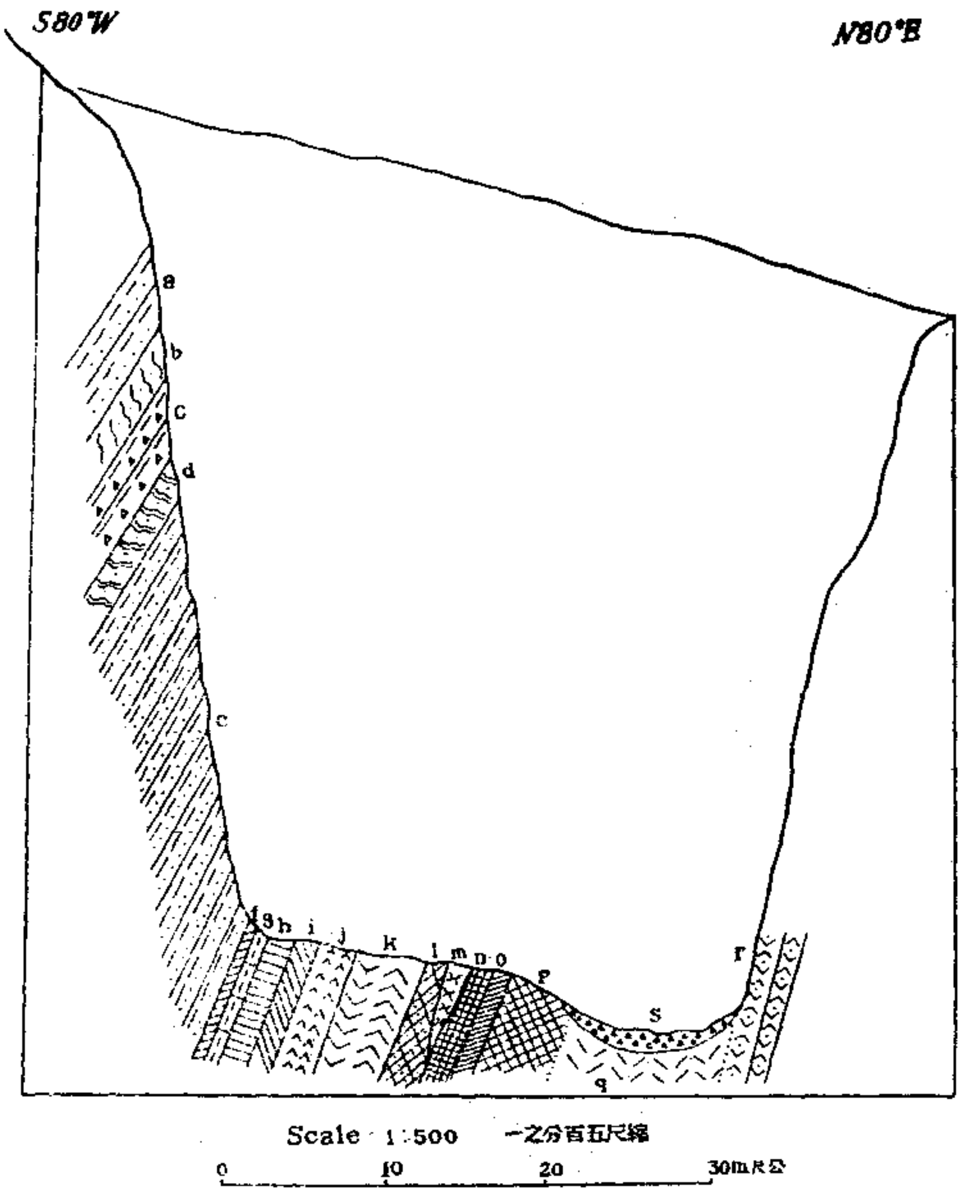
（一） 顯微鏡研究

在野外調查時，曾採有礬石標本凡二百餘塊，爲探求明礬石之產狀及其成因起見，有半數皆磨成薄片以作顯微鏡下之研究，今將所得之重要結果分述於後，惟岩石之單獨敘述，已詳英文篇中，茲姑從略。

礬石中之明礬石，以微晶及隱晶爲多，僅在二塊標本內，其晶形尙大，卽肉眼亦能辨別之。從顯微鏡下之觀察，其形體共有後列七種：（一）細長晶體（第六版第一圖，第八版第四圖），（二）細針狀晶體（第六版第二圖，第八版第一圖），（三）小碎塊（第七版第四圖），（四）短柱狀片（第八版第四圖），（五）大塊狀片，其中部有時呈劈裂線（第六版第三、四圖），（六）大梭形晶體，乃由多數

針狀體合併而成，然具有相同之光學性及方位（第六版第二圖），及（七）小鱗片（第八版第五圖，第五版第三圖）。

除體積極小之小鱗片及碎塊外，其光學性質皆能察辨，而尤以梭形及大塊狀者最爲明晰，多數晶體，皆延垂直晶軸（C）而發育，在平行扁光鏡下無色，亦無多色性，屈折光率殊高，劈開面大致與長軸（卽C軸）相平行，發育尚稱完善，有時更有斷裂面（Parting）與之直交。在直交偏光鏡下呈負號延長性（elongation）及第一級上部至第二級之干涉光，復加收斂鏡時，其正號單軸晶光學性質，卽可測定。其屈折光率自一·五九至一·五六五，最大之晶體長三·五糎寬一·五糎，外表呈淺紫色及白色，具眞珠光澤，硬度略小于四。其比重無從測定，含明礬石最多之礬石，則比水重二·七六倍。



第四圖　珠寶坑礬石礦剖面示礬石礦層次

明礬石之產狀，共有三類。第一類曰混合式（第五版第三圖，第八版第五圖），其特徵爲明礬石多成微小之鱗片及碎塊，與其他微晶或隱晶質—大部爲石英—相互混雜，四散各處

，而不結集。礬化之細凝灰岩中，此種現象，最爲普通。試設想，如上升之熱液中，僅含少量之礬化原素及化合物，而歷次上升，必間以相當之時間，則每次上升以後，卽可造成定量之小體積明礬石結晶；又如被礬化岩石，組織緻密，質性均一，則其體內各部承受礬化之機會均等，而造成之明礬石，亦散佈各處，無一定之排列或團聚成形。準此推論，此種礬石內含明礬石之多寡，似與該處礬化熱液浸入之次數成正比例。

第二類曰散佈式(第五版第四圖，第八版第一、二、三圖)，其特點爲明礬石多成針狀或細長針體，任意散列于較細之石英及其他礦物之微晶中，無一定之方向或形式以約束之。造成此種現象之岩石，其質當不甚均一，故僅局部適于礬化，且熱液上升之次數必較少，而含有礬化之原素及化合物較多，故產生之明礬雖少，其晶體則反較大。

第三類曰團集式，屬此者明礬石往往團聚成某種形體，不若前二者之分散零瑣，漫無限制，如細分之，又可依其外形而別爲四種。岩石內之裂縫及易于浸入之線縫(Line of weakness)，往往爲明礬石所充塡而造成細長之脉形(第七版第一、二兩圖)，是爲第一小類。在塊集岩及角礫岩內，則礫石間或礫石與黏合質交接之處，又易爲明礬石所代換或充塡而成不整齊之長塊形（第五版第四圖），是爲第二小類。在斑狀之火山岩內，則其長石斑晶易爲明礬石所代換，而呈長方形之團集體(第五版第二圖，第八版第二圖，第六版第三、四圖)，又凝灰岩或塊集岩之黏合質，有時局部組織鬆散，易爲礬化溶液所浸入，致造成種種不規則之明礬石集合形體(第五版第三圖)，是爲第三及第四小類。由此可見礬石內明礬石散合之形，亦非出諸偶然，蓋與其原來之成分組織及熱液之性質，息息相關，互有線索可尋。

若以生成時之情況爲據，明礬石可分爲五種，有代換岩石內之正長石或鈉長石斑晶而生成者（第五版第一、二圖，第六版第三、四圖），多見于礬化之粗面岩，粗面凝灰岩及侵入岩中；有普遍代換者(第五版第三圖，第八版第一、三、五圖)，則明礬石四散各處，多見于質較均一之細凝灰岩內，有僅代換岩石中之黏合質而生成者(第五版第四圖)，多見于組織較鬆之塊集岩或角礫內，有充塡岩石中之裂縫而成者(第七版第一、二圖)，亦有塡塞氣孔而成者。上述五類中，充塡式者甚不重要，所佔之量極少；第

四類更代表一後期之礬化作用，蓋業已礬化之岩石，常爲此種細脈所穿透，足證其生成較晚。

上述種種，多偏重于明礬石個體之形體或產狀，今將依據礬石之原來成分及其礬化之程度而劃分之，且依次列論于後。

第一類乃礬化甚淺之岩石，其本生組織尙大體保留，含明礬石較少，多不能開採以鍊明礬。此種岩石殆皆經矽化，試與未經變蝕之同類岩石相比，則質較堅硬，色澤亦略暗淡。共包有五種不同之岩石。閃長岩及粗面岩，其長石斑晶往往變蝕較甚，且有局部爲明礬石所代換者。細凝灰岩及粗面凝灰岩則由類似長石之微晶及石英細粒及小鱗片狀明礬石所組成，後二者乃次生礦物。至凝灰砂岩則往往變蝕最深，其石屑之原生成分以長石爲主，然多已變成絹雲母及高嶺土，石屑交接處，亦偶有明礬石小晶體。赤鐵礦小粒，在任一岩石中皆有之，惟其數量之多寡則大有出入。

其次爲礬化之粗面岩，含明礬石約達百分之四十，可供鍊礬之用。斑狀組織，甚爲明顯，然以變蝕過甚，致標準之粗面狀組織，則尙未之見。其斑晶以長石爲主，但大部已爲明礬石及石英所代換；亦有變解極甚之角閃石，惟不多見。基質內亦以明礬石及次生石英爲主，長石微晶次之，尙有不定量之赤鐵礦或褐鐵礦。岩石內之氣孔常局部爲明礬石或赤鐵礦所充塡。粗面岩經礬化及矽化以後，略有裂隙，而復爲明礬石，石英及赤鐵礦所充塞，呈細脈狀。

第三類爲礬化細凝灰岩及粗面凝灰岩，含明礬石約百分之四十至五十，宜于製造明礬。細凝灰岩由極細之石屑所組成，其成分以已經變蝕之長石微晶，石英細粒及明礬石爲主，後者多成鱗片狀或微小細長晶體，常散佈各處，或團聚成各種不規則之形態。粗面凝灰岩之成分，亦大致相似，但尙含有長石斑晶，有二標本且略呈流紋構造。此種岩石內，亦時有明礬石及赤鐵礦等所組合而成之細脈

第四類包有礬化之凝灰岩，火山角凝岩及塊集岩等，含明礬石之成分約達百分之四十。碎屑構造 (Clastic Structure)，多甚明顯，除少數例外，即肉眼亦能見之。黏合質往往易受礬化，所含之明礬石亦較多，此外尙含有次生石英及其他礦物。石屑或礫石閒或其與黏合質相遇之處，明礬石旣多，晶形亦較大而完整。石屑或礫石多爲酸性之火山岩，現在之成分，與黏合質內者，亦

無甚差別，其礬化程度之深淺，與其本來之組織及成分有關；如本身呈斑狀組織時，則其長石斑晶，往往易爲明礬石所代換。赤鐵礦爲常有之礦物，但以見于黏合質內者爲多，有一部份顯係次生。明礬石及赤鐵礦等所組成之細線尙爲普通。

上述四類岩石中，尙有普遍之特性凡三，頗堪令人注意之。（一）赤鐵礦常變成一乳白或黃灰色非晶質，偶呈菱形半面方格狀條痕，且尙含有小粒之赤鐵礦，此或爲一種硫酸鐵，乃由礬化溶液內之硫酸與分解中之赤鐵礦互起變換而成。蓋在一標本(R. No. 5332) 之包體中，曾見此乳白色之非晶質與業已局部變化之黃鐵礦相共生，而赤鐵礦分解後亦偶呈此菱形半面狀結構也。(二)明礬石之表面常甚光明，而長石微晶則爲雜質高嶺土所覆，致在平行扁光鏡下觀察，模糊不清，可見前者較爲穩定，不易變換及風化。(三) 長石斑晶除大部爲明礬石及石英所代換外，常局部變爲高嶺石及絹雲母，似亦由外來之溶液與之互起化學變化所造成。

第五類乃礬化極深之細凝灰岩，採自珠寶坑之P層，含明礬石達百分之六十。其成分以明礬石爲主，細石英爲副，前者多成小鱗片狀或碎塊狀，且與石英互相混雜，不常團聚成不規則之形態。

礬石顯微鏡研究之重要結果，已如上述，因此而發生之推論，以解釋明礬石之成因，當于下節討論之。

(二) 化學成分

礬化岩石之經本所熊尙元先生分析者，共有二十四種，大半皆爲可以開採之礬石。其結果分列于第一表中。明礬石之成分係根據純粹之鉀明礬 ($K_2O.3Al_2O_3.4O_3.6H_2O$) 分子式所計算，除養化鉀外，其他各分子皆有剩餘。其結果當較顯微鏡下之估計及實在成分爲低，因事實上明礬石內之養化鉀往往局部爲曹達所替換，而據分析之結果，標本內亦含有相當之曹達。似可與剩餘之鋁養，亞硫酸根及水等組合爲鈉明礬石。業已開採礬石之含明礬石平均數，約在百分之三十五至四十之間，可知其成分遠較浙江平陽者爲遜。即含蘊最富者，亦僅百分之五三·二九而已。

第一表　礬化岩石及礬石之分析表

標本號數△	標本產地*		SiO %	Fe_2O_3 %	Al_2O_3 %	CaO %	SO_3 %	K_2O %	Na_2O %	$\overset{-}{H_2O}$ %	$\overset{+}{H_2O}$ %	總種 %	含鉀明礬石之百分數
5949	珠寶坑	b	49.42	1.68	19.14	.93	18.23	2.26	3.22	.15	4.54	99.57	19.87
4960	„	d	47.06	2.19	20.10	.39	18.29	4.00	1.13	.16	7.06	100.38	35.18
4965	„	f^1	89.74	4.26	.46	微*	2.45	.55	.22	.11	.43	98.22	—
4964	„	g^1	71.37	3.01	8.83	„	10.83	2.41	.42	.01	3.43	100.37	21.19
4972	„	h	36.65	1.98	23.11	„	22.65	5.40	.75	.14	7.84	99.52	47.49
4971	„	i	58.49	2.08	15.64	„	15.33	3.74	.44	.12	5.12	100.96	32.89
4960	„	j^1	55.67	6.37	15.00	„	14.56	3.01	.61	.14	5.12	100.48	26.47
4968	„(部上)	k^1	51.96	5.77	16.03	.29	16.02	2.97	.75	.11	5.76	99.66	26.12
4966	„(部下)	k^1	48.38	8.01	16.63	.47	16.97	3.41	.55	.11	5.89	100.48	29.99
4662	„	l	46.68	4.04	18.46	微*	18.72	3.89	.34	.08	6.38	98.59	34.21
4963	„	m^1	62.81	4.22	13.10	„	12.88	2.75	.57	.07	3.99	100.39	24.18
4969	„	n	42.64	2.46	21.50	„	20.90	4.91	.56	.09	7.21	100.36	43.18
4967	„	o^1	55.26	4.25	16.05	„	15.33	3.22	.60	.10	3.13	99.94	28.32
4961	„	p	28.82	2.42	26.18	„	25.60	6.06	.38	.08	8.74	98.28	53.29
4973	„	r	47.04	3.36	19.26	„	18.31	3.42	1.41	.08	6.70	98.58	30.08
5629	羊山	2	39.21	2.96	23.32	„	21.11	4.18	1.80	.08	7.68	100.34	36.76

5621	〃 1	56.62	3.68	14.92	*	15.34	3.02	.86	.08	5.08	99.50	26.56
5339	古牛背	51.58	5.01	17.09	〃	16.09	3.48	.17	.11	5.84	99.37	30.60
5346	東山 1	48.68	2.83	19.55	〃	16.41	3.29	1.20	.10	6.75	98.81	28.93
5628	〃 2	44.89	2.83	19.15	〃	18.09	3.82	.74	.10	6.10	99.72	33.59
5360	土塘	47.11	3.97	18.96	〃	18.93	3.93	.90	.10	6.15	100.05	34.56
4974	羊山東溝中 [2]	56.91	3.60	26.51	〃	1.41	.88	.50	1.05	8.46	99.32	—
5634	天屋塘	47.56	3.48	21.78	〃	14.90	3.31	.15	.11	7.36	98.65	29.11
5631	小籠口	46.10	4.75	21.14	〃	16.63	3.89	09	.13	7.04	99.75	34.03

*其量在 0.2% 以下

★本行中之地名見第二圖；珠寶坑之各層層名見第四圖及第十一頁；羊山層名見第三圖

△岩石名稱見第二表第一行(自左至右)

[1] 未經本地居民開採以鍊礬

[2] 乃一變蝕甚深之閃長斑岩

岩石內除含有明礬石外，矽酸鹽實爲一重要成分—最多者達百分之八九．七四—大多爲次生之石英，亦有一部與剩餘之鋁養及水合成高嶺石及高嶺土。此外養化鐵（Fe_2O_3）之百分率皆在一．六八以上，多者達八．〇一，殆大半組成赤鐵礦，亦有少量之磁鐵礦。又根據顯微鏡下之觀察，岩石內亦常有絹雲母，則有一部份之養化鉀及曹達，必與剩餘之鋁養，水分及矽酸鹽化合而成此礦物焉。

(三) 比重

岩石標本之比重經作者等測定者，共有三十一塊，其中之二十四塊乃礬化而又矽化之岩石，其餘則爲業已變蝕之噴發岩。明礬石之比重，據書本所示，自二·五八至二·六八不等；茲所測定之礬石比重，則自二·四八五至二·七七。考決定比重數值之因子甚多，而岩石內含明礬石之百分數乃其最要者也。他若岩石之本生成分，組織，鬆度，礦物之大小，以及所含之其他各種次生礦物之種類與多寡，皆有相當關係。

茲將已經鑒定比重之標本名稱號數列爲第二表，依比重數值之大小，逐漸自下向上排列，顯微鏡下估計及化學分析計算所得之明礬石成分附焉。估計及計算所得成分之有差異，其理由已見前節，茲不多贅。將表中各項詳細觀察及比較後，且除去極小之例外不之計算，則自此可歸納得下述三項普遍原理：（一）如岩石之鬆度相去不遠，而所含之體重礦物極少，則其比重數值，當隨其所含明礬石百分比之高下而大致增減。（二）礬化之凝灰岩，粗面凝灰岩及粗面斑岩等皆較未受變蝕或變蝕較淺者爲重。（三）岩石之組織愈粗鬆者，其比重數值必愈低；故最鬆之凝灰砂岩爲表中各岩石之最輕者。

第二表　岩石及礬石比重表

岩石名稱	比重	岩石登記號碼	顯微鏡下估計之明礬石成分	化學分析所得之明礬石成分 %[1]	附註*
凝灰砂岩	2.34	R.No. 5343	微		探親嶺（第一版·10）
粗面凝灰岩	2.37	〃 5253	〃		載家行（第一版·7）
凝灰砂岩	2.37	〃 5347	〃		
凝灰砂岩	2.39	〃 5348	〃		東山（第一版·3）
礬化凝灰岩（略呈矽化）	2.395	〃 4965	<1%	1 %—	珠寶坑子 f 大礬山
粗面凝灰岩	2.47	〃 5256	無		載家行中部

粗面斑岩	2.475	„	5341	微		載家行（第一版·26）
礬化矽化凝灰岩	2.485	„	5974	¼±		轎子頂西南
礬化矽化凝灰岩(氣孔甚多)	2.49	„	5345	>⅓		石曹嶺北
礬化矽化粗面凝灰岩	2.49	„	4963	⅓±	24.18	珠寶坑m 大礬山
礬化矽化凝灰岩	2.49	„	5802	無		畢家老西南
礬化矽化細凝灰岩	2.51	„	4964	⅓±	21.19	珠寶坑g 大礬山
礬化矽化塊集岩	2.53	„	4973	⅓—½	30.08	珠寶坑r 大礬山
礬化矽化粗面岩	2.53	„	4971	⅓	32.89	珠寶坑i 大礬山
礬化粗面凝灰岩	2.575	„	4966	>⅓	29.99	珠寶坑k_1（下部）大礬山
礬化粗面岩	2.58	„	4968	>⅓	26·12	珠寶坑k_2（上部）大礬山
礬化粗面斑岩	2.58	„	4970	<½	26.47	珠寶坑j 大礬山
礬化矽化凝灰岩	2.59	„	4960	⅓±	35.18	珠寶坑d 大礬山
礬化矽化凝灰岩	2.59	„	4959	½	19.87*	珠寶坑b 大礬山
礬化粗面凝灰岩	2.59	„	4962	⅓—½	34.21	珠寶坑l 大礬山
礬化矽化粗面斑岩	2.605	„	5350	½		夏家院子北（第一版·22）
礬化矽化細凝灰岩	2.605	„	4969	½	43.18	珠寶坑n
礬化凝灰岩	2.61	„	5631	<½	34.03	小竈口（第一版·16）
礬化火山角礫岩	2.61	„	4967	<½	28.32	珠寶坑o

礬化塊集岩	2.615	〃	5346	>⅓	28.93	東山（第一版·1）
礬化粗面斑岩	2.615	〃	5634	<½	29.11	天屋塘（第一版·15）
礬化細凝灰岩	2.62	〃	5629	½	36.76	羊山（第一版·9）
礬化粗面斑岩	2.65	〃	5630	½	34.56	土塘（第一版·6）
礬化粗面凝灰岩	2.66	〃	5628	½	33.59	東山（第一版·1）
礬化粗面凝灰岩	2.75	〃	4972	>½	47.49	珠寶坑h
礬化甚深之細凝灰岩	2.76	〃	4961	⅔	53.29	珠寶坑P

* 地名請參閱第一版及第二圖;珠寶坑之層名參閱第四圖.

[1] 礬石成分依照 $K_2O.3Al_2O_3.4SO_3.6H_2O$ 分子式 計算,事實上 K_2O 分子每爲 N_2O 分子所局部替換,如 N_2O 分子亦計算在內,則明礬石之成分更當增高.

[2] 此標本含 N_2O 甚多,如計算成分時亦包含在分子式內,則明礬石成分應加至 35.91 %.

第二表中最下一行之標本，其比重數值，當與純粹之明礬石較爲近似，因其含明礬石既幾達三分之二，而其他之鑛物成分，又以比重略小之石英爲主也。

丙、礬石與明礬石礦量及其經濟價值

從野外觀察其產狀之結果，足知礬石層順層面向下延長尙深，其厚度雖有變化，但亦有相當限制，不致相差甚遠。如以附近地平面—較礬石大廟低二十五公尺—如其最下之限制，而估計其儲量，則所得之結果，當尙可靠。又據化學分析之結果，業已開採之礬石，其含明礬石之成分，皆在百分之三十以上；然成分之在百分之二十五至三十者，雖未開採，而實亦有開採之價值：前者爲高等或中等之礦石，後者屬低等，似應分別估定其礦量。準此二項原則以爲根據，則吾人可估計各礦層附近地平面以上之礬

石及鉀明礬石儲量于後：

（一）第一礬石層乃中等礦石，平均厚四公尺，長三百二十公尺，比重之平均值爲二・六四，傾斜四十度。其上之礬化塊集岩含明礬石達百分之二八・九三（R.No.4967），但以厚僅四十糎，長僅二三十公尺，故未計算在內。礦石露出于較地平（乃附近平原之地面，以下彷此）高約一百二十公尺之坡上，故其沿層面所量得之可採寬度爲一百八十公尺。依此計算，礬石之總量爲：

$$4 \times 320 \times 180 \times 2.64 = 608{,}256\text{公噸}$$

其所含明礬石之成分爲百分之三三・五九（R.No.5628），故明礬石之總量爲・

$$608{,}256 \times 0.34 = 206{,}807.04\text{公噸}$$

（二）第二層厚二公尺，長一百五十公尺，傾斜角自四十度至四十五度。其南端高出地平一百九十公尺，北端高七十公尺，故其可採寬度爲二百公尺。其明礬石成分及比重假定與第一層相等。其儲量分別估計如左：

礬　石：$2 \times 150 \times 200 \times 2.64 = 158{,}400$公噸

明礬石：$158{,}400 \times 0.34 = 53{,}856$公噸

（三）第三層內較佳之礦石，包括珠寶坑內之 d, h, i, l, n, p, r 及 q 等層，共厚二八・五公尺，平均含明礬石達百分之三八・三四。此二數值係根據下列算式計算所得：

厚度：$2(d) + 1.5(h) + 1.5(i) + 1.75(n) + 1.75(l) + 5(p) + 10(r) = 28.5$公尺

各層之所含明礬石之百分率：

h：47.94　　d：35.18

l：34.21　　i：32.89

n：43.18　　r：30.08

q：53.29　　q：35.00

各層所含明礬石百分率之平均數：

$$(2\times0.3518+1.5\times0.4749+1.5\times0.3289+1.75\times0.3421+1.75\times0.4318+5\times0.5329+5\times0.3008+10\times0.35)$$
$$\div28.5=0.3834=38.34\%$$

但本層全長七百公尺，其水平方向之變化必多，茲為愼重起見，假定平均厚度減為十五公尺，明礬石百分率減為三五，其平均傾斜角為六十度，平均比重為二・七〇，露頭之平均高度（高出附近地平，以下彷此）為一百三十公尺，故其可採寬度據計算所得為一百五十公尺。茲將礦量估定于後：

礬　石：$15\times700\times150\times2.7=4,252,500$ 公噸

明礬石：$4,252,500\times0.35=1,488,375$公噸

如連成分較差者亦計算在內，其厚度當增加甚多。在珠寶坑，其總厚五二・八公尺，平均明礬石成分為百分之三四・五七，此二數值係根據下列計算所得：

各層之厚度及含明礬石之百分率：

d,2公尺,35.18%;e,18公尺,28%;h,1.5公尺,47.49%;i,1.5公尺,32.89%;j,2公尺,26.47%;k,4公尺,28%;l,1.75公尺,34.21%;n,1.75公尺,43.18%;o,1.2公尺,28.32%;p,5公尺,53.29%;q,10公尺,35%;r,5公尺,30.08%.

總厚度：56.2公尺

含明礬石百分率之平均數：

$$(2\times0.3518+18\times0.28+1.5\times0.4749+1.5\times0.3289+2\times0.2647+4\times0.28+1.75\times0.3421+1.75\times0.4318+$$

1.2×0.2832+5×0.5329+10×0.35+5×0.3008)÷56.2=0.3457=34.57%.

為愼重起見，全層之厚可減至四十公尺，其明礬石百分率減至三十。平均比重為二・六八，長度與可採寬度與較佳之礦相等。故其儲量當如左列所示：

礬　石：40×700×150×2.68=11,256,000公噸

明礬石：11,256,000×0.3=3,376,800公噸

（四）第四層內較佳之礬石厚八公尺，長五百公尺，其傾斜角為三十二度，明礬石百分率為三十七（根據R.No.5629），平均比重為二・六一。露頭之南端高二百五十公尺，北端高一百十公尺，故其可採之斜面寬度為三百二十公尺。其儲量共有：

礬　石：8×500×320×2.61=3,340,800公噸

明礬石：3,340,800×0.37=1,236,096公噸

羊山之低等礬石厚三公尺，其明礬石成分為百分之二六・五六(R.No.5621)，比重為二・六，其全層之成分應減至百分之二十六，厚度減至一公尺半。其他情形與佳礦相同。據此，其礦量共有：

1.5×500×320×2.6=624,000公噸

624,000×0.26=162,240公噸

（五）第五層厚一公尺半長三百公尺，比重二・六，傾斜角三十五度。其明礬成分假定為百分之三十。其平均高度為七十五公尺，其可採之斜面寬度據計算所得為一百二十公尺。故其儲量當如下列所示：

礬　石：1.5×300×120×2.6=140,400公噸

明礬石：140,400×0.3=42,120公噸

（六）第六層內較佳之礬石厚五公尺，長一千二百公尺，平均比重二・六五・明礬石成分百分之三十二　（根據R.No.5634及5631

二(標本之化學分析)，傾斜角十八度，露頭之平均高度爲一百公尺，故其可採之斜面寬度爲三百三十公尺。據此估計，其鑛量應爲：

礬　石：5×1200×330×2.65＝5,247,000公噸

明礬石：5,247,000×0.32＝1,679,040公噸

如低等礬石亦計算在內，其厚度當增至四十公尺，而平均長度則減至九百公尺，明礬石成分假定爲百分之二十八，比重與可採之斜度寬度不變。則其儲量當如左列所示：

礬石：40×900×330×2.65＝31,482,000公噸

31,482,000×.28＝8,814,960公噸

綜上所述，從含明礬石成分在百分之二十五以上之礬石內，應取得鉀明礬石凡一三，八九二，八七九公噸；從含明礬石在百分之三十以上者提取，則可得四，六六四，一七四公噸。按本區礬石礦之起始開採，遠在四百年前，假定已經採去之明礬石總量爲一百萬噸，則現在尙存一二，八九二，八七九公噸。明礬石內含有養化鉀達百分之一一．四，故在理論上應得之養化鉀爲一，四六九，七八八噸。據本地居民之經驗，佳質礬石每百斤可得明礬二十五斤，而其平均產量爲二十斤；今如以明礬石計，其平均礬石產率可達百分之三三．三三，則今後大小礬山之礬石，如仍用土法提鍊，可得明礬之量爲四，二九七，一九六公噸，約値二萬萬元之譜。但據本所金蕭二先生(十)試驗浙江平陽礬石之結果，將礬石加熱至攝氏五百度再溶于百分之十之硫酸溶液內，所得之明礬佔明礬石重量百分之五十以上，設能研究酸性強度及去水明礬溶度之關係而改進製法，則明礬之產率更可增加；其副產品則有礬土等。又據高雅德氏 (Guyot) 之試驗，如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礦石重二．五倍之明礬，而其剩渣內尙含有少量可用之礬土(約百分之三)及硫酸鉀(約百分之二．〇一)等。可見設法改良製造明礬方法以求其之生產率增加至一倍或二倍以上，實爲當今發展廬江礬礦業之急務，然欲達此目的，以裕國計民生，則尙有待于國內化學家之努力也。

礬石除用以製造明礬外，尙可用以鍊取硫酸鉀，大戰時美國曾從事此種工業之進行。據金蕭二先生之試驗，礬石加熱至八百度後復溶于水，所得之硫酸鉀約當于明礬石重量五分之一，而附屬產品有氧化鋁，達明礬總重十分之六。硫酸鉀之主要用途，則爲肥料。

此外，礬石亦可以製作硫酸硫礦，礬土及養化鉀，惟其成本往往過重，經濟方面不甚合算，如將來之製法更精，可獲高利，則礬石用途必更增大。

上述製礬方法之改良，礬石效用之增加，乃化學家所應勵行及促成之事；然人爲之利用有限，天然之富源無窮，故新礦層之發現，舊礦層之証明其可以延長，實爲經濟上更有意義之事，凡此，尙有待于將來更詳細及精密地質工作之成就 。此種希望，非完全之理想可比，亦有實現之可能，蓋據顯微鏡研究之結果，離礦層甚遠之岩石中，尙含有明礬石約達百分之三十以上者 (R. No.5350.5345.5979等)。

第六節　礬石礦之成因及熱液變蝕(Hydrothermal alteration)

侵入岩及火山岩內，常含有次生之石英，明礬石，高嶺石(Kaolinite)，絹雲母及赤鐵礦，乃由變蝕作用所造成；變蝕作用有五：卽矽化，礬化，高嶺化，絹雲母化及鐵化作用是也。其中尤以矽化及礬化作用最爲重要，蓋石英之微晶狀結集體，在任一標本之薄片內，皆能見及，而明礬石結晶體，亦爲常見之礦物；據化學分析之結果，岩石內含石英之最高成分，達百分之八九．七四，亦有含純粹鉀明礬石多至百分之五三．二九者，高嶺石絹雲母及赤鐵礦，雖亦常見，然其量不豐。赤鐵礦從未富集成爲礦脈，僅在轎子頂有劣質鐵礦露頭一塊，但含鐵極少。盧家凹及小礬山間，火山岩皆呈凝灰質，所受之變蝕特甚，或以其組織粗鬆，故易爲熱液所滲透。

上述五種礦物結晶先後之次序，在顯微鏡下亦能粗略鑑定。石英與明礬石生成最早，二者多同時結晶，時或前者成形在先；其後卽爲絹雲母及高嶺石；生成最晚者，則爲赤鐵礦。至礬化作用，又分二期：凡火山岩之普遍礬化及礬石層之生成，皆屬第一

期；第二期則較不重要，乃明礬石及附生之赤鐵礦與石英，常成細線充塡于業已礬化之岩石內，其發生之時期，竟或在高嶺石造成以後。觀乎各種礦物產狀之邇近，關係之密切，其結晶先後之時間，必相距甚近，且在相似情況下，由同類之變蝕作用所造成。

今先將明礬石之成因討論之，其結果，于其他各種礦物生成之情形，當有所啓示。按明礬石乃一次生礦物，由含有硫酸之溶液或水素與富于鉀鋁之岩石或礦物相互交換變化而成；溶液之溫度甚低，或亦含有鉀鋁之成分，多沿裂縫或易于侵入之處上升。經顯微鏡之研究，知廬江礬石乃由凝灰岩及粗面岩等變化而成。然則，促成此種變換作用之硫酸溶液或水素，果來自何處耶？

關于硫酸之來源，綜合各專門學者之意見（十二）共有左列三說：

第一說，乃黃鐵礦或其他硫化物可養化而成硫酸，含于潛水內，自上下降，與鉀鋁岩石或礦物變換成爲明礬石。在小礬山東北之溝中，曾見一黑色火成岩包體，生於淡紫色之粗面岩內，雖亦含有黃鐵礦小粒甚多，而其露頭，尙未發現。又在顯微花崗岩內，亦偶或含有黃鐵礦，然爲數過少，決不能供給巨量之硫酸。至其他各種岩石內，則從未見其蹤跡。可知此說，不能適用于本區。

第二說，當火山岩生成時，火山口常有二養化硫噴出，可養化成硫酸，與方在凝固之火山岩，互起變化，產生明礬石。若然，火山岩所含之明礬石，更當普遍，而僅有火山岩內之鉀鋁礦物，呈礬化現象，生成較後之侵入岩內，則不應有明礬石之蹤跡；且火山岩內，亦應有黃鐵礦或其他硫化物之遺跡，以示其生成時頗富硫質。然事實上之證明，適得其反。是故此說，亦難適用。

第三說，乃侵入岩漿內常儲有二養化硫，當其隨同熱液上升時，亦可逐漸養化而成硫酸。今在礬山附近，侵入岩及噴出岩併受礬化作用之影響，凡礬石層皆與侵入岩相接近，且在侵入體之中心尙含有黃鐵礦；凡此事實，皆足表示侵入岩漿可爲硫酸之來源，而熱液上升，則較其侵入之時期稍晚。葉良輔先生等（十二）研究浙省平陽之礬石礦時，曾得相似之結論；謝家榮先生及著者等，前在當塗北鄉秦家崗—距閃長岩之露頭甚近—之火山岩內（十三），亦見有多量之明礬石，據謝先生之研究，其成因亦與酸性

侵入岩有關。可見我國東南各省明礬石之生成，皆與酸性侵入岩有關，不獨廬江一地爲然。至其所以皆產于凝灰性之酸性火山岩內，或以其組織鬆散，熱液易于上升，且含有鉀鋁質之長石甚豐，致造成明礬之機會較多。按我國東南海岸與此時代相同之酸性噴出岩及侵入岩之分佈甚廣，若準此二項原則以事搜求，則新礬石礦之發現，亦屬可能，願我地質界諸同志努力之。

上升之熱液內，是否含有鉀鋁諸質，尙不能斷言，以缺乏充分證據故也。惟據顯微鏡下之硏究，在同一標本內，有一部份長石斑晶，殆已完全爲明礬石所代換，而亦有大部變爲絹雲母及高嶺土 (Kaolin) 並不包含明礬石者；前者當爲正長石，鉀鋁之成分俱富，易與硫酸溶液變換爲明礬石，後者乃斜長石雖有鋁質，而缺乏鉀化物，故未礬化。由是觀之，熱液內所含之鉀鋁二質，恐不甚多。

調查區域內之侵入岩，多呈斑狀組織，屬半深成岩，當其生成時，溫度既較高，壓力亦尙大。礬石產地較侵入岩爲淺，其造成之溫度壓力，應更低小，但無從準確決定之。

已經礬化之火山岩，其本來之內部構造及組織，尙大部保存。長石斑晶雖多爲石英，明礬石及絹雲母等所代換，其晶形仍完整不破；可知礬化作用進行時，岩石之內部，殊爲穩定，並未發生重大變化。

考石英，絹雲母，高嶺石及赤鐵礦等四種礦物，雖在多種不同之情況下，皆能產生，然在本區內，則因與明礬石之產狀相似，關係密切，其成因當亦相同，理由已見前段，茲不多贅。

總之，本區內岩石所呈之變蝕作用，完全由來自酸性侵入岩漿之上升熱液所造成；據侵入岩性及其造成之礦物—如高嶺土絹雲母等—則此種熱液實具有中深 (Mesothermal) 及淺深 (Epithermal) 之性質。明礬石之生成，乃其重大之功績，然所產之赤鐵礦過少，致無開採之價值。南京當塗九江(十四)三鐵礦區之熱液變蝕情形，正與此相去不遠，惟彼三處之礬化作用較不重要，或竟未存在，而鐵礦之造成，則爲惟一重大建設工作。由是可知廬江礬石礦之成因，與長江下游諸鐵礦有密切之關係，且同屬中生代末或以後之產品，卽以明礬石爲鐵礦造成時副產品之一，亦無不可。

綜前所述，火山岩發生後以迄于礬石造成之重要史實，可歸納爲下列三期：（一）火山岩流繼續噴發至于地面，其間曾數度停止，而暫時爲外力作用所侵蝕。（二）然後花崗岩體侵入于火山岩系及較老之地層內，其四週分化而成斑狀組織，隨之俱來者尙有閃長岩之小侵入體甚多，但離此岩漿中心較遠。因冷却收縮之結果，侵入岩及圍岩皆有罅裂之發生。（三）沿此隙縫卽有來自同一岩漿中心之熱液上升，多浸入于組織較爲鬆軟之岩石內；熱液與圍岩互起化學變化而造成次生之石英，明礬石，高嶺石，絹雲母及赤鐵礦等，致大部岩石皆呈矽化，而少數岩層因礬化過深，卽成爲可以開採之礬石。其後，復有隙裂發生，于此卽造成明礬石，赤鐵礦及石英合組成之細脈焉。熱液初升時，溫度既高，所受之壓力亦尙大，及至上層與圍岩互起化學作用時，溫度壓力，皆已減小，凡此情形，于其所造成之礦物，可蹤跡得之。

第七節　礦業概況

據本地居民之傳說，此礦在唐時已開採採鍊，惟後卽中斷，嗣于明初復開，以迄今日。歐戰時，因礬價高漲，製礬業獲利甚厚，極盛一時，惟近已式微矣。

礬山採石製礬，皆藉舊法。礬工約別爲礦戶與窰戶二種，間接依之爲生者有草戶，車戶，簍戶，船戶，以及泥水鍋鐵等匠，約六七千人。礦戶卽採石之工人，自由散賣，業戶但得百斤五厘之租利，不得干涉。窰戶卽爲製礬之工人。大小二礬山現有礬業商廠二十家，內獨資者十九，皆爲盧姓，合資者一，資本總額達七萬餘元，礦產四千餘元，共有窰六十四座，最多者一廠不過四窰。設備大都異常簡陋，成立之先，必雇工建造草棚或瓦屋三四間至十餘間，築土窰數座，收買瓦缸及鐵鍋若干口，然後購買礬石，從事製礬。至製礬之法，甚爲簡單。礬石經工人抬運至廠，聚集成數，卽裝入窰內，乃燒以稻草，經三四夜後，石紅如炭，實已鬆散。然後取出用鐵鎚擊碎，大如雞卵，置于坑內，每隔十天潑水一次，至十次爲止，再用礬泥——製礬所餘之泥渣——封面。五六十日後，已軟如爛泥，開坑取出，和以清水，在大鐵鍋內煎熬；其後復經濾瀝，去其渣滓，將清澄液體注入缸內，經一週，明礬卽結晶而出，是謂頭礬。餘汁再煎而產第二三次之結晶，其質較劣。所產之礬，卽裝入竹簍，以供運銷，每簍重一百五十斤

，值四元上下至五元。計礬石每百斤，如製造適當，可得明礬二十餘斤，若火力失宜，或生或枯，潑水不均，或乾或濕，其產量即減。按自燒石起至煎礬止，經打石潑水等種種手續，需時半年之久，需工數十，而柴草一項尤爲製明礬大宗消耗。

按通常情形，每年明礬產額約自三萬簍至四萬簍，合二千六百七十九噸至三千五百七十一噸，價值十二萬至十六萬元。其中一部係載往蕪湖，再轉銷各地。據海關貿易冊之報告，自民國十三年至二十二年，每年由蕪湖關出口之明礬數量，當如下列所示：

年份	担數	噸數
十三年	三，〇一一	一七九·二
十四年	一，六五五	九八·五
十五年	二，八六五	一七〇·五
十六年	一，七七三	一〇五·五
十七年	一，九〇二	一一三·二
十八年	二，四八六	一四七·九
十九年	七，三六五	四三八·四
二十年	六，三三二	三七六·七
廿一年	四〇	二·四
廿二年	一一五	六·八

二十一二十二兩年在蕪湖出口量之所以稀少，或以適當蕪湖礬商與礬山廠商發生衝突之故。惟據去年十二月大公報礬山之通訊，二十二年所產之礬仍達二萬七千五百八十四簍，值洋十一萬零七百八十元，除去成本及運費（運蕪湖等地）外，約盈餘二萬

二千七百餘元，然尚須繳納捐稅云。

（一）中央研究院西文集刊第十一號，中文集刊十號，葉良輔李璜張更合著之『浙江平陽縣之明礬石礦』

（二）C. Y. Hsieh: Geology of Chunshan and its Bearing on the Supply of Artesian Wells, Bull. Geol. Soc. Clina, Vol. II, 1928 胡博淵梁津謝家榮著：首都之井水供給（地質彙報十六號）

（三）C. Y. Hsieh and othrss: Geology of the Iron Deposits of the Lowr Yangtze, Mem. Geol. Surv. China, Ser. A, No. 13,1935 pp. 8-10.

（四）仝前，英文篇頁一三—一四，及第一圖，

（五）劉季辰趙亞曾著：浙江西部之地質，（地質彙報九號）

（六）王恆升李春昱著：京粵鐵路線（南京至福建南平段）地質礦產報告（地質彙報第十四號）

（七）葉良輔喻德淵著：南京鎮江間火成岩地質史（中央研究院地質研究所專刊乙種第一號）

（八）仝（三）地質專報甲種十三號

（九）同上

（十）金開英籲之謙著：平陽礬石之加熱試驗（地質彙報二十三號）

（十一）仝上見英文篇第二十一頁

（十二）見（一）

（十三）見（八）

（十四）同上

明礬之熱解（Thermal Decomposition of alum）

楊珠瀚
金開英

一、引言

由明礬石(Alunite)製造純淨養化鋁（Alumina)之基本方法，不外以燒過之(Calcined or roasted)明礬石加入稀硫酸，結晶而得明礬（alum），嗣由此項明礬收集氧化鋁。惟後部工作又可分爲二類：（一）依 Blanc 之方法（英專賣一八一六七八，一九二二年二月十五日）通乾氫(Dry ammonia）於近沸之明礬水溶液內，而得極易過濾之氫氧化鋁（Aluminum hydroxide）。（二）以加熱方法分解明礬爲氧化鋁（Alumina）與硫酸鉀（Potassium sulphate），而以水分之。惟前法雖後人亦偶有記載，然所得之氫氧化鋁確否易於過濾，究屬不無攷慮之餘地。且氫氧化鋁之加熱以及氫之消耗亦在在予該法以打擊也。於是熱解之方法尙焉。蓋明礬之熱解除水及熱能外，幾無耗費之因子，且副產物硫酸鉀之淨度（Purity）極高，工業用途不待言矣。即用於化學藥品（Chemical or reagent）亦無不可，決不似前法之產生硫酸鉀與硫酸錏之混合物，僅限於肥田之用也。

按由明礬石製造氧化鋁之基本方法，固不僅結晶明礬之一途也。惟明礬之結晶可屏除一切雜質（Impurities），而成極純淨之雙鹽（Double salt），即以此點而論，已視任何其他方法爲優。嗣以加熱作用而得純潔之氧化鋁，亦較可靠也。

明礬之分解，前人亦有記載，特失之不詳，爰有是篇之作，或後之操是業者，庶可得而稽焉。

二、明礬之樣品

在中國市場銷售之明礬，俗稱白礬，因其係工業之產物，故除去應有之化學雜質外，尙參以灰土砂石等不潔物，設欲用爲分析之樣品，非經初步之處理不爲功，其法無他，即以原明礬加水煮溶，然後過濾，以屏除不溶解之雜質，嗣蒸發此濾液，并使結晶而得明礬。惟此種明礬尙嫌不純，故必測定其熔點，是否恰合公認之熔度（攝氏九十二度），不合則應行再度結晶（Recrystallization），以達標準之熔點爲止。

然後以此種高凈度之明礬，進行基本之化學分析，以測定其化學元素之成分，而資佐證焉。茲將所應用之方法，簡括述之於後：

I　氧化鋁—秤〇·二五克（Gram）之明礬溶解於一百立公分（C.C.）之水中，加入氫氧化錏（Ammonium hydroxide）以沉澱氫氧化鋁，并加熱使其膠結，然後以定量濾紙濾之，先洗以氯化錏（Ammonium chloride）溶液，繼之以熱水者約六七次，或以無硫酸基（Sulphate radicle）爲度，嗣以此項沉澱納入磁杯內燒至熾熱而成氧化鋁，一俟後者冷却，精密秤之，而以氧化鋁之百分率表出之。

II　三氧化硫（Sulphur trioxide）—將上項濾液加入鹽酸，酸化後煮之，迨其沸騰，許許滴入十立公分之氯化鋇溶液（百分之十）Barium chloride solution 10%），頻攪以玻棍（Glass rod），并使繼續沸騰約半小時，然後安置溫處過夜，翌日濾之，并洗以熱水以無氯基（Chloride radicle）爲度，一俟洗滌完畢，即將該硫酸鋇（Barium sulphate）納入磁杯內，燒至熾熱，俟冷後秤之，嗣由此項數字計算而得明礬內三氧化硫之含量焉。

III　氧化鉀（Potassium oxide）—明礬內氧化鉀之測定，著者曾用下列二法：

1硫酸鉀法—即以上項硫酸鋇之濾液（Filtrate）煮沸，滴入淡硫酸以去鋇鹽（Barium salt），而將此項濾液蒸發使乾後秤之，嗣由此項乾燥硫酸鉀之重量計算明礬內氧化鉀之含量。

2過氯酸鉀法—直接以II條硫酸鋇之濾液蒸發約至十立公分，加入足量之過氯酸（Perchloric acid），蒸發至近乾，加入十立公分之水及三立公分之過氯酸，再度蒸發，以過氯酸氣體起始發散爲度，然後再以十立公分之純酒過氯酸混合物加入該經蒸發之物內，而以顧氏濾杯（Gooch crucible）濾之，頻洗以純酒過氯酸混合物，并使乾之於百〇五度，然後置入三百至三百五十度之電爐內燒半小時卽妥，俟冷秤之，并由此過氯酸鉀之重量以求得氯化鉀之含量。

右列二法在無鈉鹽（Sodium salt）存在之下，當以前法較爲准確而簡便也。

IV 結晶水之測定—秤二．五克之明礬盛諸十立公分之鉑杯內，燒至四百度，并存留於此溫度至重量不再遞減爲止（需時五小時），其所損失之重量即表示結晶水之重量，此項測定以用管狀立式電爐（揮發物測定爐）爲最適宜。又明礬經熔化後繼續加熱，每易濺散，故在此種情形之下切勿使溫度增高過劇。

本明礬由上列方法所測定之分析，結果如下：

表一：明礬之化學成分

	測定之值	計算之值
氧化鋁	一〇·六〇	一〇·七四
三氧化硫	三三·七〇	三三·七五
氧化鉀	*（一）九·八五 （二）一〇·〇五	九·九三
結晶水	四五·五九	四五·五八
總計	（一）九九·七四 （二）九九·九四	一〇〇·〇〇

*註（一）由過氯酸鉀法所測定之值

（二）由硫酸鉀所測定之值

三、溫度於熱解之影響

物質之熱解因溫度之增高而加劇，殆爲普通之事實，明礬當亦能以此律繩之。惟明礬之爲物，就化學家之見地言之，係硫酸鋁與硫酸鉀所合成之雙鹽，熱力之影響於硫酸鋁與硫酸鉀之分解者必不一致。著者爰就此點研求，以期獲得分別此二種物質之基礎焉。

在上項肯定目標之下，最先所應探討者，厥惟明礬之一般分解—即各個溫度下所進行之總分解也（受熱後之總減重 Totaloss on Ignition）。茲述其測定方法如次：

秤二・五克之明礬於鉑杯內，燒於指定之溫度，直至重量不再遞減爲止，而秤此餘剩物，以測定明礬於該指定溫度下所受損失之總量。其分析結果如下：

表二：

溫度（攝氏）	總減重（百分率）	加熱時間（小時）
一〇五	二七・七七	四〇*
一五〇	四四・七八	五*
二〇〇	四五・二一	五
三〇〇	四五・五〇	五
四〇〇	四五・五九	五
五〇〇	四五・七一	八
五五〇	四六・二三	一二*
六〇〇	五三・〇一	三〇*
六五〇	五八・六九	一〇*
七〇〇	七〇・四七	一八
七五〇	七〇・四八	七
八〇〇	七〇・四八	三、五
九〇〇	七〇・五〇	三

九五〇	七〇·七九	二

*分解未完成

設由表二之結果，繪製圖線（第一圖之曲線I見英文本篇），當能明晰明礬之分解確有兩個階段。由一〇五度起至二百度以迄五〇〇度爲第一階段，在此階段內只有結晶水被熱解以去。由五〇〇度而上至七〇〇度以迄九百度或九百五十度爲第二階段，硫酸鋁之分解即成功於此階段。如溫度繼續加高，則必有分解硫酸鉀之第三階段出現也。惟著者爲本文之範圍所限，未事深求耳。

本測定以其爲間斷方法，所需之時間恆較繼續或一次加熱所需之時間爲長。例如燒明礬於九百度，應於半小時內完全分解（見後）。而此處則需至三小時之久，此殆因燒過之明礬爲不良導熱體，雖爐中之熱度已達所需之溫度，然明礬本身所受之熱度，則當低於此度者多多。及後明礬本身到達應需之溫度時，時間已耗費良久矣。

明礬之揮發物係由水及三氧化硫所組成，設已知其一，則其他成分不難計算得之，明礬之結晶水，前面已有精密之測定，故三氧化硫之含量，即以此項水分爲根據，依次計算出之，如表三：

表三：

溫度（攝氏）	驅逐之水（百分率）	驅逐之三氧化硫（百分率）
一〇五	二七·七七	〇
一五〇	四四·七八	〇
二〇〇	四五·二一	〇
三〇〇	四五·五〇	〇
四〇〇	四五·五九	〇
五〇〇	四五·五九	〇·一二

五五〇	四五・五九	*〇・六四
六〇〇	四五・五九	*八・四二
六五〇	四五・五九	一三・一〇
七〇〇	四五・五九	二四・八八
七五〇	四五・五九	二四・八九
八〇〇	四五・五九	二四・八九
九〇〇	四五・五九	二四・九一
九五〇	四五・五九	二五・二〇

*分解未完成

上項結果前已言之，係完全基於固定之水分（四五・五九）而計算得之，是其間難免發生錯誤，著者爲期深一步之認識起見，而應用可靠之分析方法，以資參證焉。法卽以燒就之明礬逐一測定內含之硫分如下：秤約〇・二克之試料加水煑之，并濾去不溶解之物質，而將清液煑沸，許許滴入氯化鋇溶液，則其中之硫酸基將俱與鋇鹽化合成硫酸鋇而沈澱，後者一依前述之處理秤定之，嗣由此沈澱物之重量以計算三氧化硫之含量，則其間三氧化硫之是否經過分化而損失，抑損失至何種程度，當可一目瞭然也。玆將其分析之結果整理列出之，如表四：

表四：

溫度（攝氏）	燒就之明礬之硫分	理論之硫分	三氧化硫之損失
三〇〇	六〇・三〇	六二・〇二	一・七二*
四〇〇	六一・九五	六二・〇二	〇・〇七

K_2SO4

五〇〇	六一・五二	基於 $Al_2(SO_4)_3$	六二・〇二	〇・五〇
五五〇	六一・〇七		六二・〇二	〇・九五
六〇〇	—		—	—
六五〇	—		—	—
七〇〇	二九・一〇	基於 $Al_2O_3K_2SO_4$	二八・九九	—
七五〇	二九・一一		二八・九九	—
八〇〇	二九・一〇		二八・九九	—
八五〇	二九・〇四		二八・九九	—
九〇〇	二九・〇五		二八・九九	—
九五〇	二八・四七		二八・九九	〇・五二

三百度以下，決無分解三氧化硫之可能，茲不贅。又就上表之數字觀之，三百度時似已有三氧化硫發出。然以大勢度之，謂甚屬不確。著者意，該度下硫之稍低者，當係明礬中尚有最後之水分未被馳散有以致之耳。

由表三或表四，可繪製圖線如第一圖之曲線II（水之驅逐）及圖線III（三氧化硫之驅逐），（俱見英文本篇）。

四、明礬在固定温度下進行分解之速率

温度之於分解明礬之影響，前已言之詳矣。而在某固定温度之下，加熱時間之久暫，亦予該分解以極大之影響，時間愈久，分解之程度亦愈深，惟每一固定之温度，自有其特殊之分解率。且達某種限度，將永久保持常態，決無進行再度分解之可能。

明礬之分解率當依下法測定之：

秤二·五克之明礬於鉑杯內，燒於應需之溫度，幷按時將鉑杯取出，秤其所受損失之重量，直至重量不再遞減爲止，而得如下之分析結果：

表五：

一〇五度	時間（小時）	¼	½	1	2	3	6	10	13
	減重（百分率）	六·四三	一〇·二五	一五·一六	一八·三三	二〇·四〇	二三·一一	二四·六六	二五·三三
	時間（小時）	十六	十八	二十	二十五	三十	三十五	四十	
	減重（百分率）	二五·七七	二六·〇三	二六·三三	二六·七六	二七·一三	二七·四〇	二七·七七	
一五〇度	時間（小時）	½	一	二	五				
	減重（百分率）	四三·七三	四四·六〇	四四·七〇	四四·七六				
二〇〇度	時間（小時）	½	一	二	五	七			
	減重（百分率）	四四·六八	四五·〇八	四五·一三	四五·三三	四五·三三			
三〇〇度	時間（小時）	半	一	三	五	八			
	減重（百分率）	｜	｜	四五·二四	四五·五〇	四五·五〇			
四百度	時間（小時）	半	｜	二	五	八			
	減重（百分率）	｜	｜	四五·二四	四五·五九	四五·五九			
五百度	時間（小時）	半	一	三	五	八	｜		
	減重（百分率）	四五·六〇	四五·六三	四五·六六	四五·七〇	四五·七一	四五·七一		

五五〇度		六〇〇度				六五〇度				七百度				七五〇度	
時間（小時）	減重（百小率）	時間（小時）	減重（百分率）	時間（小時）	減重（百分率）	時間（小時）	減重（百分率）	時間（小時）	減重（百分率）	時間（小時）	減重（百分率）	時間（小時）	減重（百分率）	時間（小時）	減重（百分率）
¼	四五·七三	½	—	十七	五一·一七	¼	四六·三一	十二	六二·九六	¼	四七·九六	十二	六九·六四	¼	五四·六〇
½	四五·七四	一	—	二十	五一·六四	½	四六·七九	十四	六四·一七	½	四九·七三	十五	七〇·三九	½	五六·八五
一	四五·七六	二	四六·五三	二十五	五二·一九	一	四七·五五			一	五二·七六	十八	七〇·四七	一	六四·一一
二	四五·八四	四	四七·五六	三十	五三·〇一	二	四九·四一			二	五六·八三	二十	七〇·四七	二	六七·四四
八	四六·〇四	六	四八·三六			四	五三·〇一			四	六二·七〇			三	六八·七六
十	四六·一五	八	四九·三三			六	五四·二五			六	六五·四四			四	六九·五四
十二	四六·二三	十	五〇·〇一			八	五六·〇三			八	六七·四三			五	七〇·〇九
		十五	五〇·八五			十	五六·六九			十	六八·六八			七	七〇·三五

八百度	時間(小時)	½	一	二	二·五	三	三·五	四
	減重(百分率)	六八·七三	六八·八六	六九·九七	七〇·二六	七〇·四三	七〇·四八	七〇·四八
九百度	時間(小時)	¼	半	一	一·五	二	三	
	減重(百分率)	六九·六五	七〇·六九	七〇·七三	七〇·七五	七〇·七七	七〇·七九	

由上表(表五)之結果繪製圖二(見英文本篇)。

該圖之曲線可歸納之爲二類，而以五百度線爲界。五百度以下之曲線，係表示明礬內結晶水之發散率，而五百度以上則表示硫酸鋁內三氧化硫之發散率，雖後者依然有水之驅逐率在內，然在較高之溫度，水之發散應完成於最初數分鐘內，是以此項水份之發散，固不能應響三氧化硫之曲線也明矣。

又由上表所示，在一〇五度幾不能使水分全部發散。設溫度高至一百五十度，并與以充分之時間，全部水之驅逐，可得而致。惟時間之延長，無論如何爲一殊不經濟之舉，故二百度始能謂爲驅逐水分之有效溫度耳，同理五百五十度及六百度亦不能使硫酸鋁全部分解，而六百五十度必在充分時間之下，方可使分解完成，故七百度而上，始爲有効之溫度焉。

五、分解明礬爲氧化鋁與硫酸鉀之溫度及其與時間之關係

由前列表二及圖一，吾人當能明了三氧化硫之原始出發點爲五百五十度。然在此項溫度之下，此發散率甚屬低微，燒至累日恐亦不得完成，卽增高至六百五十度亦不無同感(三十小時之久亦未見完全分解)，惟至七百度其分解率始差強人意。著者遂以此度起始而進行如下之測定：

秤二·五克之明礬於鉑杯內，納入電爐中，燒至指定之溫度及經固定之時間後取出，溶解於熱水而後濾之，嗣由此濾液觀察鋁鹽，以氫氧化錏。設分解完成，則無氫氧化鋁沈澱。蓋分解後之氧化鋁不溶解於水故也。其所得之結果如次：

表六：

溫度	時間
七〇〇	十五小時
七五〇	五・五小時
八〇〇	二・五小時
八五〇	一小時
九〇〇	半小時
九五〇	四分之一小時

以上之測定概以一次燒就者爲限，設第一次分解未完成，則應取另一試料重新測定。

由上表（表六）之結果可繪製圖三（見英文篇）

六、氧化鋁之淨度

由上列諸溫度所燒就之明礬研碎并加水煮之，其中之硫酸鉀溶解以去，而將此不容解物納入電爐中乾之，而施以氧化鋁之測定如下：

秤〇・〇五至〇・〇七克之試料於矽杯（Silica crucible），加硫酸氫鉀（Potassium bisulphate or Potassium pyrosulphate）熔融，一俟氧化鋁全部熔解，納入玻杯，加水煮之，可得完全清液。嗣以足量之氫氧氫水，許許滴入，則氫氧化鋁沈澱以去，一如前述之方法，測定其含量。

據試驗結果由本方法可得淨度九九・七五之氧化鋁

七、硫酸鉀之收集

燒就之明礬加水煮之，硫酸鉀全部溶解於水，前已言之。而以過濾手續，屏除不溶解之氧化鋁，然後蒸發此濾液并使結晶而收集之，是爲硫酸鉀。此種結晶體以理度之，當無其他雜質之存在，惟爲分析者之計，再度結晶究屬必要也。著者爲求得此二種結晶體之淨度起見，愼密的進行化學元素分析如次：

秤乾燥之硫酸鉀於燒杯內約〇・一五克，加二百立公分之水煮之，待其沸騰，加入十立公分氯化鋇溶液，而測定其中之硫酸基，一如前面所述。嗣以淡硫酸加入該濾液以去鋇鹽，而以硫酸鉀法測定其中氧化鉀之含量。茲將其結果及淨度列表如下：

表七：

	三氧化硫	氧化鉀	淨度（以So_3爲根據）
初度結晶之硫酸鉀	四五・五〇	五三・九〇	九九・〇四
再度結晶之硫酸鉀	四五・七〇	—	九九・四八
理論之成分	四五・九四	五四・〇六	一〇〇・〇〇

八、中國明礬之儲量

中國明礬石之儲藏以浙江平陽一帶爲最富，安徽次之。其他如江西等處，亦有存儲。平陽一帶之儲量，前據葉良輔先生調查，有礦石二十萬萬噸，姑以含明礬石百分之五十計算，則可得明礬石十萬萬噸。最近由本所陳愷君從新估計，其數字稍有出入。陳君調查平陽之富礦石（含明礬石百分之六十）有二三五、七二三、七五〇噸，貧礦石（百分之三十）三一七、〇二八、〇七四噸，共計可得明礬石二三六、五四二、六七二噸。據金蕭二君之結果，明礬之產率爲明礬石之百分之七十四，則平陽之明礬石可產明礬一七五、〇四一、五七七噸。換言之，可得原質鋁一千萬噸，氧化鉀一千七百三十八萬噸（約當硫酸鉀三千二百十五萬噸）。又安徽廬江之明礬石之儲量，據謝程陳三君調查，約當平陽儲量十分之一，則總計此二處之儲量，可得原質鋁一千一百萬噸，氧化鉀一千九百十二萬噸（約當硫酸鉀三千五百三十七萬噸）。姑以該二物現行市價估之，則鋁可售價一百五十萬萬元，硫酸鉀售

價二百餘萬萬元。明礬石中硫酸每感不足，勢必額外加入方足成明礬，是以硫酸爲本方法之惟一物質消耗。惟該酸於熱解明礬時一部分逸出，因得收集移用於初步工作，消耗當不甚大也。

九、結論

I 鉀明礬之去水溫度爲由三百度乃至五百度，而以四百度爲最有效之溫度耳。

II 硫酸鋁之起始分解約在五百五十度，惟就本文之結果觀之，七百度以上方屬有效之溫度，而以八百五十度爲最適宜於明礬之分解。惟溫度高至九百五十度，則似有分解硫酸鉀之虞(?)。

III 一應燒礬工作必穩必愼，否則熔化之明礬，加熱過劇恆被濺出，致失分析之意義也。

IV 最高淨度之氧化鋁，當能由此法得之，本文所得之數字爲百分之九九・七五。

V 硫酸鉀之淨度可高至百分之九九・四八，設再三結晶，必能得到更爲純淨之結晶也無疑。

VI 明礬經加熱而放散水汽之時，其體積膨脹極劇，此種現象必予工業之設備管理以及效率上以相當之困難與妨碍，深望有志之士審愼攷慮之也。

鳴謝

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湖南常寧桂陽錫砒礦報告

王竹泉　熊永先

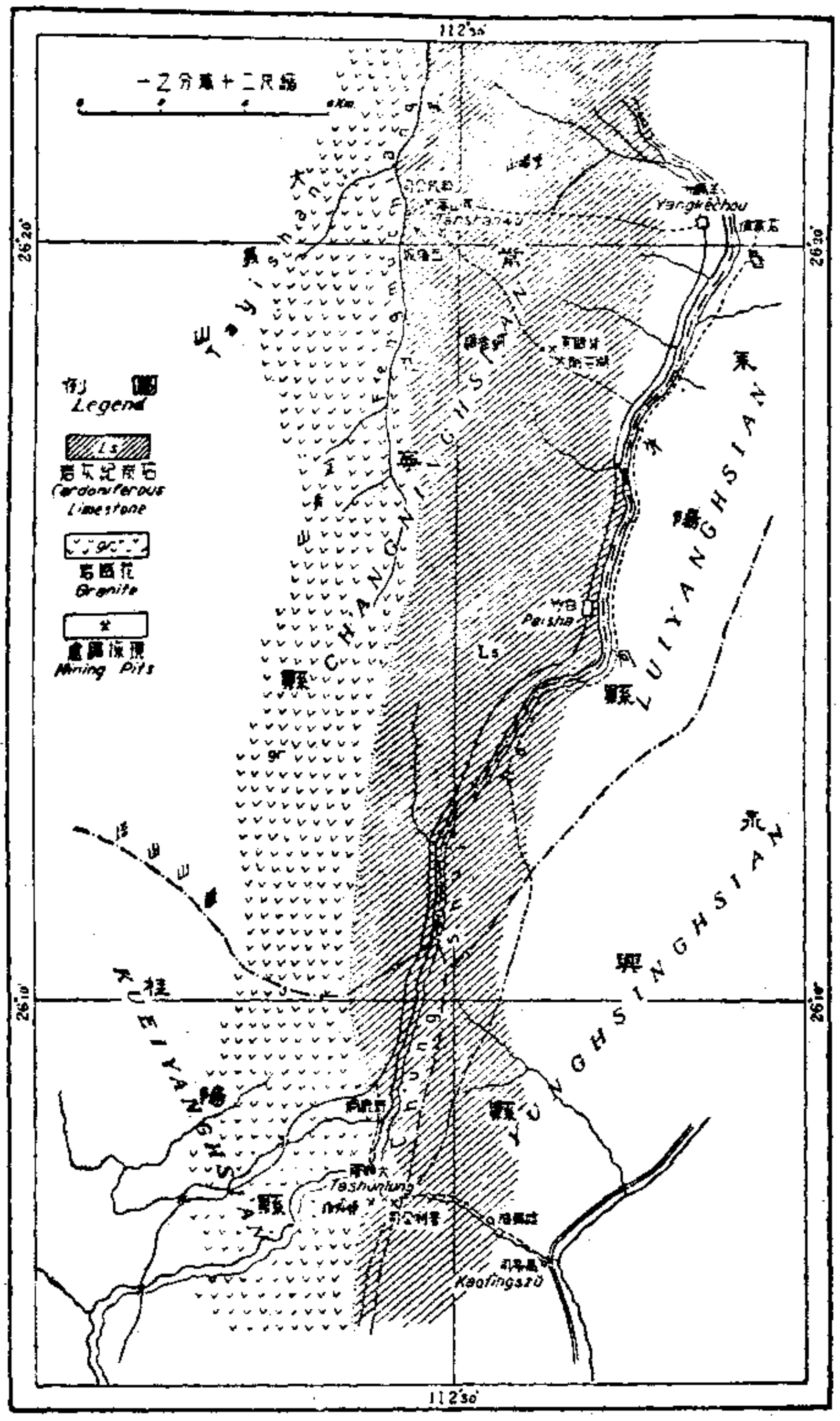
緒言

湘南錫砒礦久已著稱國內，向少從科學方面作具體之研究，自經湖南地質調查所調查，刊于該所經濟地質誌第十一號，乃益爲人注意。民國二十一年冬，作者因資源委員會之委託，考察湖南礦產，除湘潭錳礦水口山黃鐵礦別具報告外，是篇所述，專關於常寧北成窿及桂陽大順窿等處錫砒礦。特注意於礦體之形態，與礦物之組織，以及礦業成因等，試分述之于左。

地形

此次調查錫砒礦，係由水口山鉛鋅鑛廠前往。計水口山距北成窿約八十餘里，中經秧田衡頭諸市鎮，沿路所見皆係倭小山脊，高出谷面約由數十公尺至百餘公尺，而孤立之小山，尤爲常見。各山脊之間，恆列有廣闊平坦之農田，寬度有時可達四五里。由侵蝕之狀態察之，頗似華北之唐縣期地形。但自衡頭而西南望，則山嶺綿互，高出山足農田，可達二百至三百五十公尺。由山足而涉峯巔，勢極陡峻，初意一至山頂或可遙望北成窿，或尙須繞踰數次深峻之溝谷。孰知登山頂而四望，乃覺所莅之峰巔，非一單簡之山脊，實一緩坡起伏之山原（第一版第一第二圖）。此山原地形仍代表一侵蝕極深之老壯地面，脊嶺高于原谷，亦約由數十公尺至百餘公尺。故由水口山至北成窿所見地形之發育，顯可分爲二期。一爲舊老壯地面之保留，高出現在舂水河谷，約在二百至四百公尺，其地面之蝕成，頗似在第三紀始新統以前。蓋始新統之紅色頁岩與砂岩，廣布于下述新老壯地面之上者，在舊老壯地面則絕跡，此雖可以完全被蝕去解之，然終有所難通。二爲新老壯地面之造成，當舊老壯地盤重新上升，以致侵蝕復盛，卒至達于老壯地形，此種工作之開始，或在第三紀中期與後期，約在始新統砂頁岩已沈積之後，或與砂頁岩之傾側，有相當關係，故始新統砂頁岩購成之丘陵，現亦呈老壯地形。

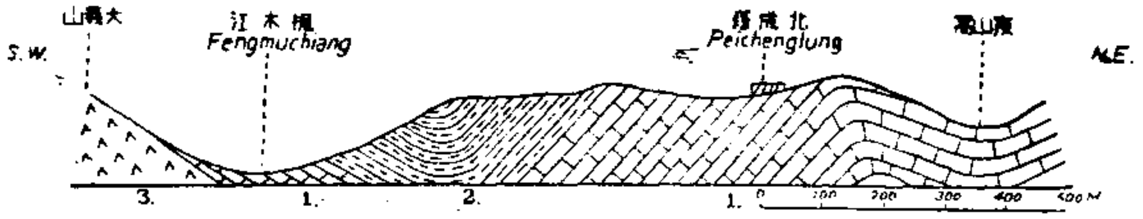
舊老壯地面因在北成窿附近大部係石灰岩構成，沿谷底每溶蝕石孔（Sink hole），以致谷內之水，悉從石孔入地，組成地下河。久之溝谷下游位於石孔之下者，逐漸高起，遂生成奇異之谷形，水系亦發生變態。



第一圖　湖南常寧桂陽錫砒礦地質圖

地質概要

北成鑪附近地層，從前田君奇㻪曾分爲錫礦山石灰岩與萬羅山石灰岩測水煤系三組，前者屬于上泥盆紀、後二者則屬于石炭紀。關于地質構造，田君曾推定楓木江與北成鑪之間，錫鑛山石灰岩自成一向斜層，北成鑪與炭山窩之間，又自成一背斜層，以致萬羅山石灰岩與測水煤系，得沿背斜層之東翼漸次露出。據作者之觀察，楓木江與北成鑪間之向斜層，似尚在田君剖面第二圖所指向斜層之西，組成向斜層之岩層，則大部屬於白砂岩與黑色頁岩（第二圖），偶含有植物化石踪跡，或者屬於田君之測水煤系，故其下之石炭岩，約亦非錫鑛山石灰岩，或已屬于田君之萬羅山石灰岩。照此推測，則似北成鑪附近無錫鑛山石灰岩，皆係萬羅山石灰岩，有時含燧石結核甚夥，當石灰岩現露層序不清晰時，可利用此結核排列之狀況，以定傾斜之方



第二圖　北成窿至楓木江間地質剖面圖

1. 石炭紀灰岩　2. 石炭紀砂岩及頁岩　3. 花崗岩

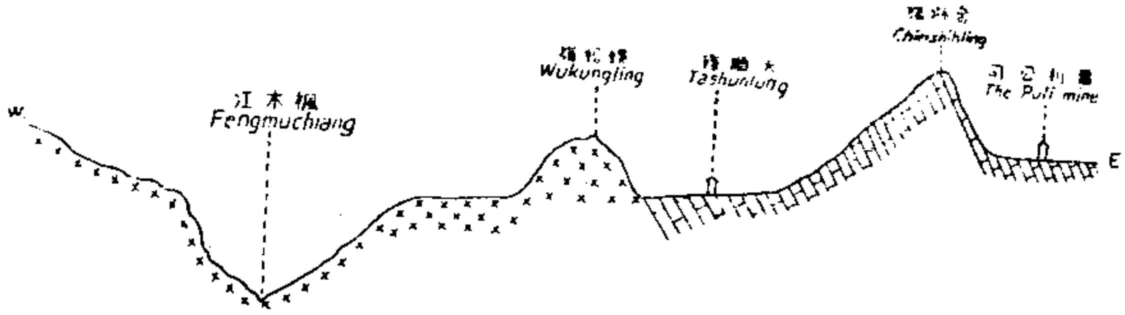
向。石灰岩風化面，恆有化石現露，大抵以珊瑚類與碗足類爲最多，所採化石數種，經計榮森氏鑑定，謂屬于上泥盆紀至石炭紀。北成窿西之測水煤系，分布面積雖廣，但大部爲冲積層與樹木所覆蔽，僅在陡碼頭沿小路兩旁，頁岩與砂岩略有露出，此是否相當于田君之測水煤系，尚無化石以資証明，惟由地層構造推測，似應與田君之羊隔州附近測水煤系相當，無可疑也。

北成窿萬羅山石灰岩之西，沿楓木江一帶皆係花崗岩，石灰岩因而變質甚深，一部變爲大理岩，而石灰岩則南經南窿天寶窿更廣布于川眼背倒石湖等處。由北成窿至倒石湖長達十餘里，廢錫砒鑛窿陸續相望。

大順窿礦場位于倒石湖之南，相距約三十五里，從前田君奇㻪曾將該處地層分爲萬羅山石灰岩與梓門橋系，皆屬于石炭紀。其接觸處則定爲逆掩斷層，重要之根據，則以二岩系之傾角不同，及萬羅山石灰岩上有條痕與角礫狀現象爲證。據作者所見大順窿附近之角礫岩，其礫石悉爲石灰岩，大小極不規則，大者長可半尺，小者徑僅數分，皆爲紅色細砂所粘結，條痕不甚清晰，其成因可有三種解說。一卽如田君所推定，係一種逆掩斷層之角礫岩，惟其上所覆之岩層，大部已被蝕去，僅金獅嶺尚有殘餘。二假定爲古河床之沉積物，但因沉積甚速，故得現角礫狀。三假定爲古冰河之遺留殘跡，金獅嶺與蜈蚣嶺間之低凹地帶，適代表一古冰河床。

以上三說究以何說爲適當，可以比較而推知。蓋如假定爲斷層角礫岩，何以礫石間皆爲紅色細砂粘結，細砂從何而來，何以在金獅嶺山坡沿假定之斷層線，反無此種角礫岩現露，此斷層角礫岩說之不易通也。若假定爲古河床沉積物，則礫石之角稜，似完全未受冲蝕，礫石大小相差甚鉅，又似完全未經水力之選擇，此又河床沉積說之難通也。若假定爲古氷河殘跡，則各礫石之角稜與粘結物之細砂，皆易解

釋，而第三圖所示金獅嶺與蜈蚣嶺間之地形，頗似代表一V字形之氷河谷。若此氷河遺跡說果可成立，則此氷河之時期，應在舊老壯地面蝕成之後，第三紀始新統以前。蓋所假定V字形之氷河谷，實位于舊老壯地面之上，高出羊隔州白沙一帶春水河畔之新老壯地面，約在三百公尺以上也。惟氷河遺跡之判定，于中生代末期中國南部氣候之變遷，極關重要，當湖南他部及其鄰近省分，尚未發見他種氷河證跡以前，自應特別愼重，不過經此次之研討，如能引起地質學者對此問題特加以注意，則他日之証明，自正可蹺足而待。大順窿附近之石灰岩，田君雖假定相當于萬羅山石灰岩或梓門橋石灰岩，實則變質甚深，大部爲大理岩，化石極不易得，大致傾斜東向約在三四十度，作者則以謂歸于梓門橋系，似較適宜。蓋如歸于萬羅山系，則大順窿與金獅嶺間之逆掩斷層，既不可信賴，何以在此無測水煤系露布：大順窿之東，逾金獅嶺，則見有黑色頁岩與砂岩，再東則爲灰色石灰岩及黃色頁岩，傾斜完全一致，田君統歸之于梓門橋系。總之在北成窿與大順窿附近地質尚未完全調查完竣，化石採集不足時，詳爲判定其地層時代，極感困難。故此次繪地質平面圖時，未敢襲用萬羅山測水梓門橋等專名，而僅以石炭紀地層籠統稱之，以待將來詳細調查該處地質時，再爲細別。但事實上不惟大順窿西之花崗岩與楓木江沿岸之花崗岩露頭連絡，應係同一侵入體，卽北成窿附近之石灰岩，亦實與大順窿附近之石灰岩陸續相望，地質時代自應相近。



第三圖　金獅嶺與楓木江間之地形地質

馬來半島爲世界產錫之中心，其錫礦礦床亦大部位于石炭二疊紀石灰岩之內。由此可知錫礦由湖南經廣西以直至馬來，其地質狀況悉大致相同。

岩石

花崗岩

北成鑑西沿楓木江花崗岩露布頗多。所含長石悉呈白色，大部結晶均細，但亦有時粗大構成斑晶，晶體之長者可達兩公分。石英量亦甚著，結晶體之大者直徑可達一公分。黑雲母恆較長石與石英結晶微細，但在所採標本表面上亦極易察出。若將標本製成薄片，用顯微鏡察之，長石變質頗深，大部變爲高嶺土白雲母及絹雲母等，正長石之苛斯伯雙晶線（Carlsbad twin），有時尙可見。正長石之外，斜長石亦頗多，其量或與正長石略相等，甚至多于正長石。故楓木江之花崗岩，實際上已近于二長岩。斜長石之反覆雙晶線，有時尙易辨認，光之屈折指數近于一·五三，大抵屬于鈉長石。當鈉長石之變質深時，反覆雙晶線恆不易辨，以致鈉長石與正長石之區別，在顯微鏡下有時感覺困難。但正長石之光屈折指數近于一·五二五，可用爲二石鑑別之資助。

大順鑑西蜈蚣嶺花崗岩（第一版第三圖），雖與楓木江花崗岩相連，但長石斑晶在此益爲顯著，黑雲母亦較在楓木江特多，石英則反較少。在顯微鏡下察之，長石多變爲高嶺土，絹雲母甚少，正長石似較鈉長石爲多，故蜈蚣嶺乃眞正花崗岩。黑雲母有時變爲綠泥石。最特異者則爲弗石甚夥，在顯微鏡受光晶光鏡下窺之，則剖面粗而突起，表示光性之負屈折率甚大，在直交扁光鏡下察之，則完全消光。

以楓木江與蜈蚣嶺之花崗岩作一比較，楓木江花崗岩內石英多雲母少，從此一方面論，似較偏于酸性，但多鈉長石，從他一方面論，又可謂較偏于基性。蜈蚣嶺花崗岩則雲母多石英少，但多正長石及弗石。故此兩種花崗岩雖所結成之礦物，量各不同，其岩漿之成分與酸性之程度，實皆相等。

田君奇㻪在楓木江之西曹家冲附近，所見之花崗岩，含有毒砂錫石及黃銅礦黃鐵礦等。此次因未渡楓木江，未見此種花崗岩。

楓木江與蜈蚣嶺花崗岩，曾經熊永先君親自化驗，其成分如左。

		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O	H_2O
楓木江	Per cent	75·51	0·07	13·32	0·16	1·29	0·02	0·02	0·61	5·16	4·22	0·06	0·40

楓木江	Mol. prop.	1·253	0·001	0·130	0·001	0·018	0	0	0·011	0·083	0·045	0	0·021		
蜈蚣嶺	Per cent	71·71	0·03	13·12	0·22	2·60	0·50	0·18	1·63	5·20	5·68	0·09	0·41	0·02	0·06
	Mol. prop.	1·195	0	0·128	0·0014	0·036	0	0·0045	0·029	0·084	0·060	0·001	0·022	0·001	0·002

將上列化學成分，若變爲礦物成分，則如左表。

	石英	正長石	鈉長石	鈣長石	鈉輝石	Na_2OSiO_2	透輝石	紫蘇輝石	弗石	黃鐵礦	磁鐵礦	燐灰石	鈦鐵礦
楓木江	27·66	25·02	43·492	0·556			2·228	0·92			0·23		0·15
蜈蚣嶺	20·70	33·36	35·63		0·46	1·83	5·99	1·78	0·07	0·12		0·34	

由礦物成分推測其岩漿性質如左。

	Class 1	Order 4	Rang 1	Subrang 3
	$\left(\frac{Sal.}{Fem} > \frac{7}{1}\right)$	$\left(\frac{Q}{F} < \frac{3}{5} > \frac{1}{7}\right)$	$\left(\frac{K_2O' + Na_2O'}{CaO'} > \frac{7}{1}\right)$	$\left(\frac{K_2O'}{Na_2O'} < \frac{5}{3} > \frac{3}{5}\right)$
楓木江	$\frac{96.782}{3.492} > \frac{7}{1}$	$\frac{27.66}{69.068} < \frac{3}{5} > \frac{1}{7}$	$\frac{9.38}{0.11} > \frac{7}{1}$	$\frac{4.22}{5.16} < \frac{5}{3} > \frac{3}{5}$
蜈蚣嶺	$\frac{89.69}{10.59} > \frac{7}{1}$	$\frac{20.70}{68.99} < \frac{3}{5} > \frac{1}{7}$	$\frac{x}{0} > \frac{7}{1}$	$\frac{5.68}{4.20} < \frac{5}{3} > \frac{3}{5}$
	Persalane	Britannare	Liparase	Liparose

由右表可知楓木江與蜈蚣嶺花崗岩，其岩漿性質皆相似，而屬於同一組，與顯微鏡下觀察之結論，適相脗合

白雲石大理岩

北成隴與大順隴附近石炭紀石灰岩，大部變爲白雲石，經風化之後，每顯示奇異之形狀，本地人嘗謂探尋礦苗須在此奇異之白雲石中。實則重要之錫砒礦，泰半蘊藏于白雲石大理岩，而此白雲石化作用與礦之聚集，確有密切關係。但由顯微鏡下細察錫

砒礦石，發見白雲石恆被矽酸鹽礦物交換，頗似石炭紀石灰岩先經白雲石化作用一部變爲白雲石大理岩，次經礦液侵入，始發育礦體，因白雲石易與礦液發生感應，故礦床多含於白雲石大理岩。而北成窿礦洞內白雲石大理岩及方解石大理岩，皆曾經本所化驗室分析，其成分如左：

		CaO	MgO	CO₂	R₂O₃	Insol matter
白雲石大理岩	1.	31·25	21·03	47·23	0·16	0·45
	2.	31·06	21·58	46·30	0·37	0·66
方解石大理岩		50·82	4·27	44·09		0·54

礦床

礦體形態

自楓木江至蜈蚣嶺花崗岩之西，沿接觸帶石炭紀石灰岩變質甚深，已詳述于前。此變質石灰岩乃爲一重要產錢砒礦之區域，現在尚在開採者，則爲北成窿川眼背倒石湖大順窿等處。北成窿礦洞內分天地人和四莊，所謂莊者卽地下工作之塲所也。最重要者爲地字莊，當作者調查時，只有此一莊尚在工作，實則地字礦苗，卽從前廢礦洞稱爲北窿者所遺留之礦體，現在工作完全追縱礦體。若按窿內從前採礦遺留之殘跡考之，其橫斷面大致成一橢圓或長方形，有時礦體特別膨漲，構成礦囊，卽所謂礦砂湖，統計礦體寬度約由一尺至三尺，高度約由一尺至兩丈，當高近兩丈時，本地卽加以砂湖之名。現在正在採礦之處，寬約二尺，高約三尺，因採此礦之順成公司無窿內測量，故礦體之眞正形態，頗難以剖面圖表明之。據作者在窿內之觀察，礦體之走向似大致由西南而東北，上部頗平緩，下部則甚急陡。

人字莊所採之礦苗，係由地字礦苗分出，可視爲地字礦之分苗，其橫斷面似呈一環狀，高寬各約尺許。和字礦苗亦係地字礦苗之一小分支，其橫斷面亦爲環狀，直徑僅四寸餘，但分出後復與地字苗合爲一體。此次曾採得圓筒狀礦體標本數塊（第三版第

一、二圖及第五版第二圖第六版第一圖），極爲美麗。天字礦苗卽從前稱爲南窿者遺留之礦體，其橫斷面呈橢圓形，寬僅三寸高約五寸，實際上已無開採之價値，聞從前開採天字礦之上部時，寬度曾達數尺，高度曾達丈許，蓋亦礦砂湖也。從前所採南窿北窿之外，尙有所謂中窿者，其礦苗現已完全失蹤，不復能尋見。北窿之北，相距約數丈，有一廢溜子窿，係閃鋅礦，其礦體形狀，本地人多已不能詳述。

北成窿之東南，相距約八里，爲川眼背砒礦，現由椿順公司開採，其礦體之橫斷面，略呈環形，高寬各約由五寸至尺許，但從前在礦體上部曾遇一大砂湖，高寬各達丈餘。川眼背之東南相距約二里許，爲倒石湖錫砒礦，現爲水淹沒，惟從前開採所遺留之礦洞，寬高各達數丈，其礦體約亦近不規則之橢圓狀，聞曾產礦砂甚夥，原爲一重要之礦區。

倒石湖之南，相距約三十里，爲大順窿錫砒礦，其礦體橫斷面略呈橢圓形，向北偏東蔓延，初名爲日字號礦，在窿內曾見從前兩大砂湖遺留之礦洞，一高約丈許寬約兩丈，一高約七八尺寬約丈許。日字號礦體之下部，復分爲三支，其橫斷面皆仍現橢圓形。一爲洪字號，寬約六寸高約二尺，一爲黃字號，寬約一尺高約三尺，一爲星字號，寬約八寸高約三尺。大順窿之東，相距約三里，爲普利公司砒礦，其礦體之橫斷面，亦略呈橢圓形，寬約一尺高約三尺，更有一分支，橫斷面則呈環形，高寬各約尺許。普利公司之南，相距二百餘公尺，爲宏益公司砒礦，從前產砒甚多，現已停工。其他若普利公司礦洞附近，更有閃鋅礦脉，寬約尺許。金獅嶺及大順窿西，沿花崗岩與石灰岩之接觸，則有赤鐵礦體，內含錫石，亦間有開採者。

統計北成窿至大順窿一帶之錫砒礦，主要礦體之橫斷面，恆呈橢圓或長方形，其狀態頗類似一方烟筒斜插于地內，惟體多灣曲，且恆澎漲或縮小耳，現已探知之深度，如在北成窿可達百餘公尺，但礦體猶未見縮減，又礦體澎漲處構成之礦囊，率距地面較淺，此亦應特注意者也。主要礦體分出之支礦，則橫斷面每爲環形，其狀態大致似圓筒。茲考世界產錫最著之馬來半島，其礦體形態，亦多管狀，故世界重要錫礦之礦體，似多爲管形，湖南南經廣西卽連于馬來半島，組成世界最重要之錫礦帶，其礦體亦呈世界特異之形態。

礦物組織

各礦體之主要成分，雖有錫砒兼產，或僅產砒石之別，其位置之排列，皆沿石炭紀石灰岩與花崗岩之接觸帶，綿亙達四十餘里。玆將各礦體由西北而東南，試分述其礦物組織于左。

成礦礦物

一、北成隆錫砒礦

北成隆錫砒礦位于上述礦帶之西北端，爲礦帶中產錫最盛之地。礦體內最多之礦物，爲毒砂錫石與黃銅礦，幾占主要礦物全部百分之九十，而毒砂一種已占百分之五十以上。此三種礦物恆組成帶狀或環形之結構（第四版第一圖），大抵最外之帶或環，每多毒砂，近中心以黃銅礦爲特著，錫石則時介于二者之間。此種結構之生成，當由于三種礦物呈節序之圍岩交換所致，自與低溫礦床充塡于裂隙，現美麗對稱之帶狀結構者有別。三種礦物之外，尙有黃錫礦斑銅礦閃鋅礦斜方硫砒銅礦及等軸硫砒銅礦等，但除斑銅礦外，非用顯微鏡不易察出。

毒砂　自標本表面察之，毒砂似可分爲塊狀體與單獨完好晶體兩種。單獨晶體多呈柱狀，有時長度可達四五公厘，散布于錫石黃銅礦或附生礦石之內。因毒砂在主要礦物中爲量最多，其塊狀體之大者，有時重可達數十斤。若將標本磨製光面在顯微鏡下窺之，卽此塊狀體亦悉現完好晶面，斜方橫斷面尤爲常見，就橢圓形或圓形礦床之全體而論，此塊狀體更恆與錫石及黃銅礦交互組成帶狀結構。

毒砂爲礦體中沉積最早之礦物，凡與錫石接觸之部分，皆現少許被交換之形跡（第六版第三圖），以致沿接觸帶恆構成極不規則之鋸齒狀態。其與他礦物接觸如黃銅礦斑銅礦等，亦呈同樣被交換之形態。

錫石　此礦物多呈塊狀，所採集之標本，僅有一塊白雲岩，晶粒甚粗，內合結晶完好之錫石，直徑可達三四公厘，其餘率不易辨其晶形。色澤以深棕色爲最常見，間亦有黑棕色者，若磨製薄片置於顯微鏡下察之，則概呈棕黃色，但分布甚不均，偶現帶

狀組織（第十版第一圖）。裂隙頗夥，平行於柱體之解理，有時亦甚明晰，結晶面多不完整，用於反光顯微鏡所製之光面，錫石恆成特別粗凸不平之狀。其被交換之殘餘晶粒，時被黃錫礦與黃銅礦包圍，表示黃錫礦與黃銅礦皆較錫石沉積稍後。而錫石與毒砂黃銅礦等，更易交互構成寬厚之帶狀組織。錫石在礦體內之含量，雖遠遜於毒砂，但其對于開礦者之重要性，則高出於毒砂之上，因純錫之價多於純砒之價，幾在五倍以上也。

黃鐵礦　此礦物爲量極微，僅于一塊標本內見有少許被交換之殘餘晶粒。其與毒砂錫石等之關係，因未見互相接觸，極不明晰。但可斷定其沉積較黃銅礦爲先，且有時被黃銅礦交換。

黃銅礦　礦體內毒砂之外，應以黃銅礦爲最多，但因提煉銅質非易，採礦者恆棄置不用。普通多呈塊狀，卽置於反光顯微鏡下之光面，亦難辨其品形，恆組成寬帶，其沉積約可分爲三種時期。所採之標本大部爲第一期沉積之黃銅礦，其光面在直角聶谷爾下察之，微顯非均質性，有時更呈反覆雙晶線。間可見黃銅礦含有閃鋅礦細脉及屑片，或閃鋅礦包有黃銅礦之殘餘晶粒，顯示黃銅礦被閃鋅礦交換之表證。最常見者爲黃銅礦內時包有許多黃錫礦之細脉或屑片，其位置之排列，恆略相平行，似沿有一定方向，頗近文像連晶組織（第七版第二圖）。此種現象如非表示黃錫礦在黃銅礦內呈非混合結構（Exsolution texture），卽應爲黃錫礦交換黃銅礦之証，如係交換之証，則似黃錫礦同時在黃銅礦內發生于許多點，以致構成近于文像連晶之組織。又見有較大之黃錫礦屑片，恆包以黃銅礦之外環，或卽爲表示黃錫礦由中心向外交換黃銅礦之現象（第七版第一圖）。

較大之黃錫礦屑片，更每含黃銅礦細格，搆成非混合結構（第七版第三圖）。此種黃銅礦之生成，似與黃錫礦同時，當較第一期黃銅礦稍後，玆稱爲第二期黃銅礦之沉積。斑銅礦往往亦含有黃銅礦之屑片（第八版第一圖），則黃銅礦似又有交換斑銅礦之形跡。當斑銅礦含有裂隙時，更易見黃銅礦之針狀細脈，沿裂隙之四周，恆略示垂直于裂隙之現象（第七版第四圖），初視之亦頗近似格狀之非混合結構，但此種細脈，不沿裂隙則極爲稀見，當因黃銅礦溶液沿裂隙易于侵入斑銅礦，自與非混合結構在斑銅礦沉積時卽已分出，與後生之裂隙無關者有別。故此種斑銅礦內之黃銅礦，應沉積在斑銅礦之後，玆稱爲第三期之黃銅礦沉積

。總計第二第三期之黃銅礦，皆爲量甚微，且非用顯微鏡無由察出，自難與第一期之黃銅礦比衡，蓋礦液內所含之黃銅礦，雖繼續沉積之時間甚久，但百分之八十以上，已在第一期沉積完畢也。

閃鋅礦　此礦在反光顯微鏡下，因呈均質性，棕黃痕粉，及深灰色澤，尙易與黃錫礦區別。且時被黃錫礦之細脈或屑片交換（第六版第四圖），完全爲塊狀不易察其晶形，其量遠遜於黃錫礦，僅於一二塊標本所製之光面內見之。

黃錫礦　此礦似與黃銅礦關係非常密切，在反光顯微鏡下，不惟時見黃錫礦交換黃銅礦，而黃錫礦又恆含黃銅礦細針，構成格狀之非混合結構（第七版第三圖）。此種黃銅礦格狀細針有兩種方向，相切略成正角，大概係沿黃錫礦之立方解理所致，有時更有一種方向與前二者斜切，或者係沿黃錫礦雙晶面之結果。所有黃錫礦在顯微鏡下概呈塊狀，晶形極不明晰

斜方硫砒銅礦　此礦所製之光面，置于反光顯微鏡下，顯示強烈之非均質性，色澤由綠藍以至紅棕，有時並可見反覆雙晶線，許多晶粒恆聚集于一處，各呈其燦爛之色性。當斜方硫砒銅礦與斑銅礦接觸時，其交界多顯緩曲狀，不易辨晰何者爲交換礦物及何者爲被交換礦物　但有時斜方硫砒銅礦與毒砂之間，夾有斑銅礦狹帶，又頗似因斜方硫砒銅礦與毒砂之接觸帶，易爲沉積斑銅礦之礦液侵入，而斑銅礦之狹帶，適爲交換斜方硫砒銅礦所致，故斑銅礦之沉積，似應較斜方硫砒銅礦稍後。

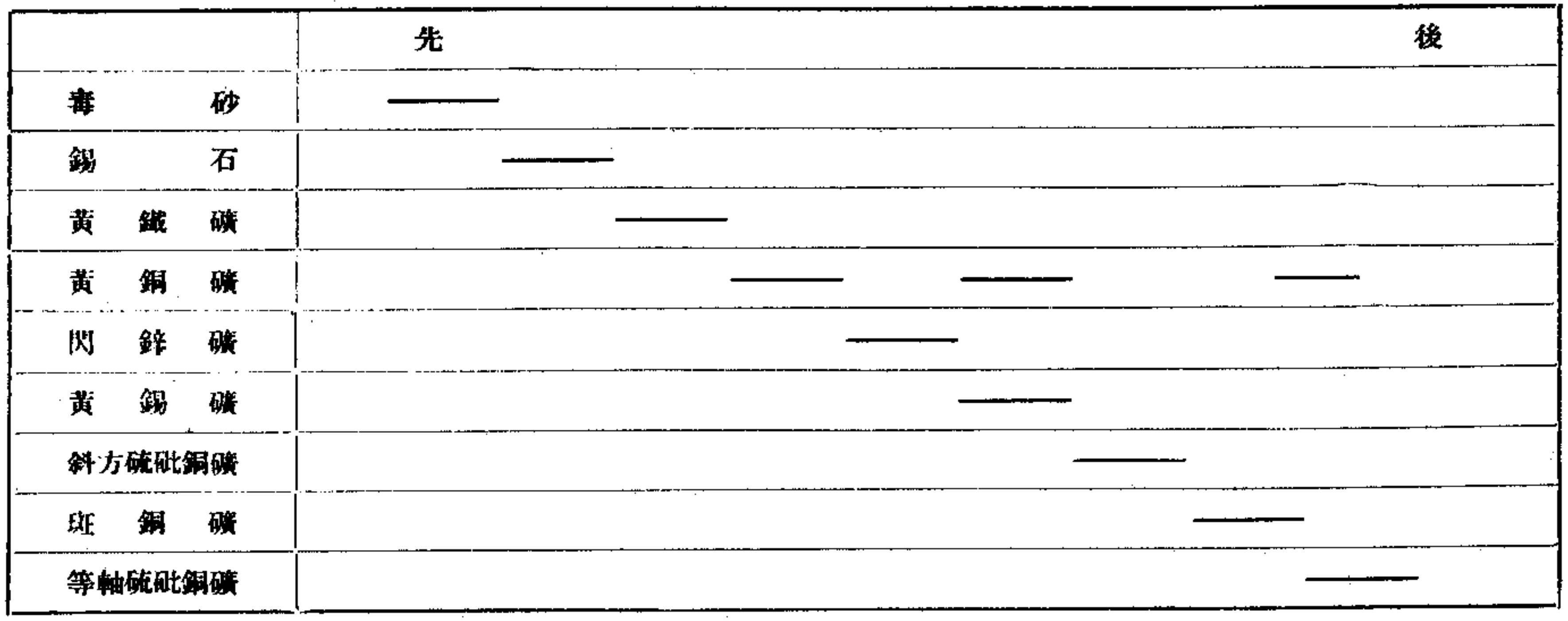
等軸硫砒銅礦　此礦物因爲量甚微，其在反光顯微鏡下之認識，尙不甚確定。若用佛爾氏所定之藥劑試之，除硝酸稍有感應外，其餘概無作用。對反光呈均質性，色澤灰白，其與斜方硫砒銅礦之關係，甚不明晰，惟有時露布于斜方硫砒銅礦與斑銅礦之接觸帶，或者表示其沉積稍後于斜方硫砒銅礦

斑銅礦　含此礦之標本，因帶有紫色及綠藍色澤，尙易于認識。若磨製光面置於反光顯微鏡下，則恆呈細脈與屑片，伸入于黃銅礦內（第七版第四圖），表示交換黃銅礦之證。但沿斑銅礦之裂隙或邊緣，則見有黃銅礦之長條或屑片，亦時侵入斑銅礦，故黃銅礦一部似又交換斑銅礦。前述黃銅礦時，曾稱此種黃銅礦爲第三期沉積，應屬各種礦物沉積之最後者。

上述各種礦物，若按其在礦體內含量之多寡，分定其先後次序，則(一)毒砂(最多)，(二)黃銅礦，(三)錫石，(四)黃錫礦

，(五)斑銅礦，(六)閃鋅礦，(七)斜方硫砒銅礦，(八)等軸硫砒銅礦，(九)黃鐵礦。

但各礦物沉積之次序，則如下表所示。



二、溜子窿高溫閃鋅礦脈

北成窿之東南，相距約里許，有名溜子窿者，現已廢棄，其礦體形態不甚明瞭，或者係脈狀。作者曾在舊洞口拾得標本數塊，携歸磨製光面，知其含有下列諸礦物。

毒砂　礦體內沉積最早之礦物，仍爲毒砂。惟含量甚少，僅見星列之晶粒，散布于圍岩與脈體之內。

磁黃鐵礦　晶體概爲塊狀，顯示強烈之非均質性，呈牛酪色與紅棕色。恆含有許多裂隙，縱橫于光面之上，大抵由于磁黃鐵

礦沉積後，收縮所致。頗似磁黃鐵礦未沉積之先，在礦液中呈膠質狀，故能于沉積後收縮，倘此種解說果確，寔于經濟地質界含有重要意義，因在高溫礦脈中能有膠質沉積，近來經濟地質學者雖已有發見，而磁黃鐵礦之呈膠質沉積，則據作者所知，似尚未之聞。又此種裂隙除　部爲黃鐵礦充填外，更有一部分爲閃鋅礦裁割，故磁黃鐵礦之沉積，應先於黃鐵礦與閃鋅礦。但有時亦可見磁黃鐵礦與黃銅礦同呈細粒，含于閃鋅礦內，構成所謂非混合結構，故磁黃鐵礦似沉積之時間甚久，一部在黃鐵礦與閃鋅礦之先，一部則與閃鋅礦同時沉積。偶有毒砂之殘餘晶粒，包於磁黃鐵礦之內，可爲毒砂被磁黃鐵礦交換之証，更常見磁黃鐵礦由毒砂之中心，向外交換，構成所謂向邊交換式。

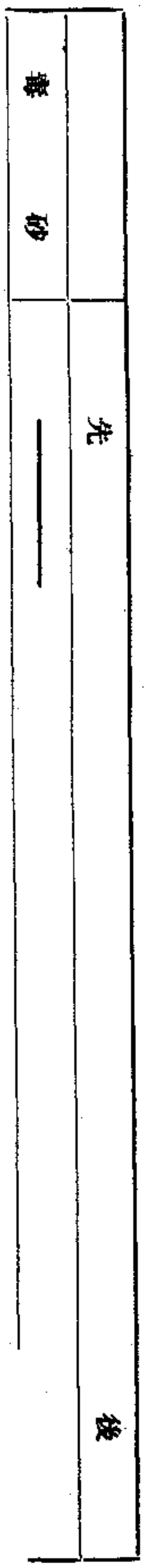
黃鐵礦　磁黃鐵礦及閃鋅礦內，恆含黃鐵礦細脈，頗似所述兩種礦物，皆沉積于黃鐵礦之先。惟閃鋅礦內亦時含黃鐵礦晶體，或殘餘晶粒，又似黃鐵礦一部沉積較閃鋅礦更早，或因黃鐵礦沉積之時間甚久，雖大部較閃鋅礦爲先，一小部則反在閃鋅礦之後。

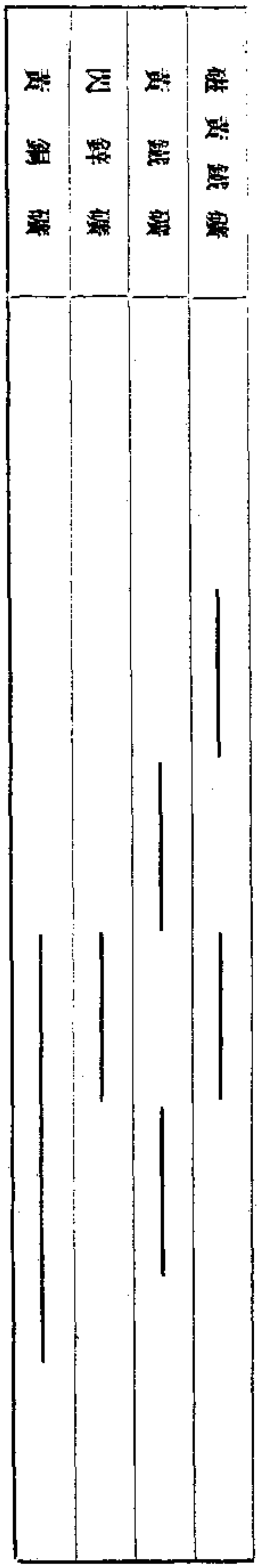
閃鋅礦　此礦爲礦體內含量最多之礦物，故名溜子窿。其所含磁黃鐵礦與黃銅礦組成非混合結構之細粒，及所含黃鐵礦細脉，恆排列于一定方向，而略相平行，大低由于閃鋅礦解理或反覆雙晶線之影響所致。

黃銅礦　除含于閃鋅礦內之細粒，係與閃鋅礦同時沉積外，大部塊狀黃銅礦，似均較閃鋅礦爲後。

統計溜子窿礦體各礦物之含量，以閃鋅礦爲最多，黃銅礦爲最少。其含量次序，（一）閃鋅礦，（二）黃鐵礦，（三）磁黃鐵礦，（四）毒砂，（五）黃銅礦。

各礦物沉積之次序，則如下表。





礦體內之礦物，爲毒砂黃銅礦等軸硫砒銅礦閃鋅礦黃鐵礦等，卽將所携標本置于反光顯微鏡下察之，亦尙無錫石發見。又各礦物除毒砂外，其餘皆含量甚少，開礦者之重要目的，只在採取毒砂，製煉砒石。

三、川眼背砒礦

毒砂　此礦約占礦物百分之八十以上，恆呈細晶密布于矽酸鹽與方解石等礦石之內。且時被矽酸鹽或黃銅礦細脈分割（第八版第二圖），故其沉積自應較矽酸鹽及黃銅礦等爲先。惟此種分割係由于毒砂沉積之後，曾遇一種急烈之擾動，以致毒砂晶粒破碎，後來之礦物與礦石，乃從事充塡交換。而毒砂破碎之裂隙，在磨製之光面上，卽不用顯微鏡亦極易察出。毒砂標本之大者，往往重數十斤，自表面察之，幾悉屬毒砂及少許礦石而已。

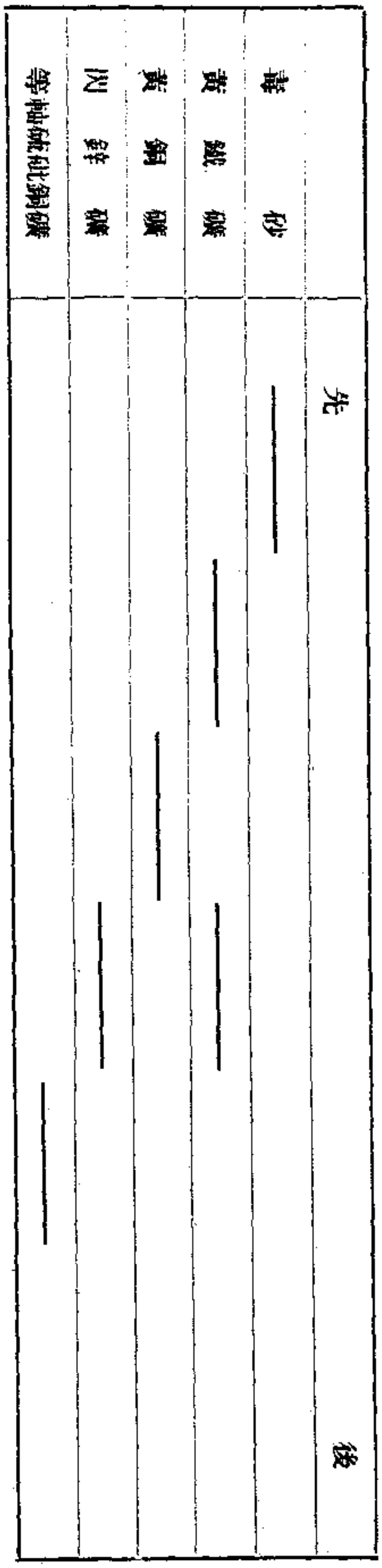
黃鐵礦　此礦只在反光顯微鏡下發見寥寥數晶，亦恆被礦石細脈分割。其與毒砂之關係，不甚明晰。僅見有殘餘之晶粒，包於黃銅礦之內，或呈脈狀穿割黃銅礦晶體，故其沉積時間應甚久，一部較黃銅礦爲先，一部則較黃銅礦爲後。大塊標本之表面，黃鐵礦極爲稀見。

黃銅礦　大部標本內皆含黃銅礦甚少，且每顯示被礦石交換之跡，但亦有少許標本黃銅礦聚集特多，黃色纍纍，甚易爲人注目。所有黃銅礦與黃鐵礦，似亦于沉積後，復被破碎，然後始有礦石之充塡交換，此種破碎，在磨製之光面上，亦甚易辨認。

閃鋅礦　此礦含量亦甚少，僅爲黃銅礦之交換礦物。其交換黃銅礦及被等軸硫砒銅礦交換之跡，極爲明晰。

等軸硫砒銅礦　此礦僅含于黃銅礦或閃鋅礦內，呈微小之細脈，故其鑒定頗難確實。然其沉積爲各礦物之最後者，則甚爲顯然。

總計各礦物沉積之次序，則略如下表。



若按各礦物之含量，以定其次序，則（一）毒砂，（二）黃銅礦，（三）黃鐵礦，（四）閃鋅礦，（五）等軸硫砒銅礦。

又各礦物與礦石之沉積，約可分爲三種時期，中間各隔以強烈之攪動。（一）毒砂沉積時期，（二）毒砂破碎時期，（三）黃鐵礦黃銅礦及閃鋅礦等軸硫砒銅礦等沉積時期，（四）黃鐵礦黃銅礦等破碎時期，（五）礦石沉積時期。

四、倒石湖錫砒礦

倒石湖原爲產錫甚著之地，惜作者調查時，適已停工，所採標本大部爲從前開礦時遺留之廢石。其所含之礦物，爲毒砂錫石黃銅礦磁黃鐵礦黃鐵礦閃鋅礦等。

毒砂　晶粒恆聚集構成帶狀組織，磨製之光面，每顯示裂隙縱橫，大抵由于沉積後曾被破碎所致。置于顯微鏡下，此種裂隙皆已爲礦石所充塡，但毒砂晶體之斜方斷面，有時尙能辨識。

錫石　此礦多爲細粒或微晶，亦恆組成礦帶。有時殘餘晶粒包於黃鐵礦之內，表示其沉積先於黃鐵礦，惟與毒砂之關係，則不甚明瞭。所製之光面，置於顯微鏡下，略顯非均質性，松脂色之內部反光，有時不易察出。

黃鐵礦　此礦大部爲殘晶，包于磁黃鐵礦（第八版第三圖）或黃銅礦之內。

磁黃鐵礦　晶形不易辨，恆含于黃銅礦之內，狀如羣島（第八版第三圖），其被黃銅礦交換之狀況，極爲顯然（第八版第四圖）。

黃銅礦　此礦含量甚富，僅次於毒砂，每爲矽酸鹽之柱狀晶體分割（第十一版第二第三圖）。其與磁黃鐵礦之接觸帶，則時被閃鋅礦交換。

閃鋅礦　此礦非用顯微鏡不易察出，只見有少許屑片，含于黃銅礦或磁黃鐵礦之內。

統計各礦物沉積之次序，則（一）毒砂（最先），（二）錫石，（三）黃鐵礦，（四）磁黃鐵礦，（五）黃銅礦，（六）閃鋅礦（最後）。

又各礦物在礦體內之含量，則（一）毒砂（最多），（二）黃銅礦，（三）錫石，（四）黃鐵礦，（五）磁黃鐵礦，（六）閃鋅礦（最少）。

五、大順廠錫砒礦

以上所述之四礦，皆屬常寧縣，大順廠則屬桂陽。雖亦錫砒兼產，但砒多錫少，礦業不如北成廠之盛，其所含礦物如左。

毒砂　此爲礦體內最多之礦物，恆聚集爲塊狀，在顯微鏡下晶形大致完好，有時散布於黃鐵礦或他種礦物之內，而呈殘餘之圓粒。又晶體每顯示裂隙，似於沉積後曾被破碎，并可見黃鐵礦黃銅礦等充塡于裂隙之內。而毒砂之被黃鐵礦黃銅礦交換，更爲常見。

錫石　此礦之晶體，恆交換毒砂，或侵入其裂隙，故錫石之沉積，應在毒砂破碎以後。錫石與黃鐵礦之關係，因接觸甚少，頗不明晰，但據他礦體內二礦物之狀況推之，黃鐵礦沉積應較錫石爲後。

黃鐵礦　此礦在礦體內含量雖不甚多，但亦可局部聚集特著，易於爲人注意。因恆被他種礦物交換，完整晶形頗爲難覩，有時可見其殘餘晶粒，完全包於閃鋅礦或黃銅礦之內。

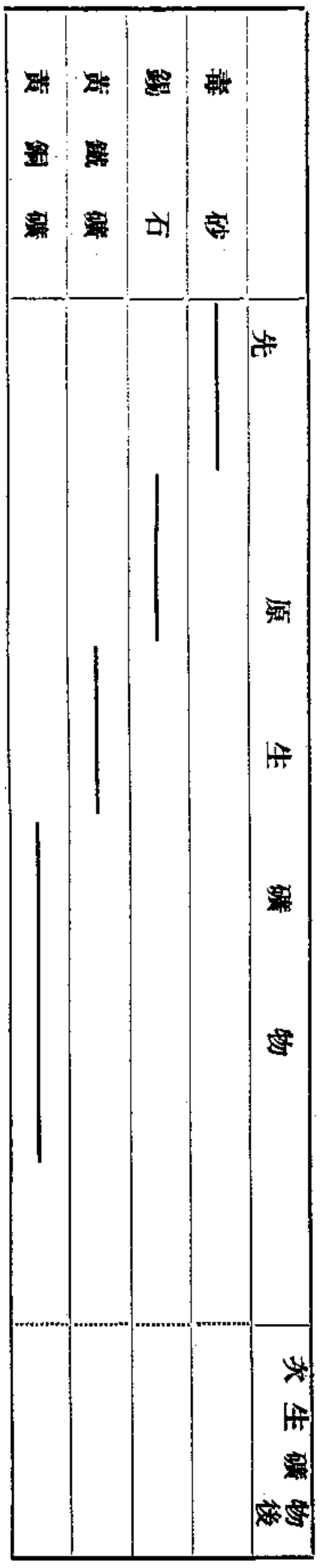
黃銅礦　大部黃銅礦之沉積，皆較閃鋅礦爲先，且每爲閃鋅礦交換。但較黃鐵礦爲後，自甚明顯，因時有黃鐵礦之殘晶，包于黃銅礦之內也。

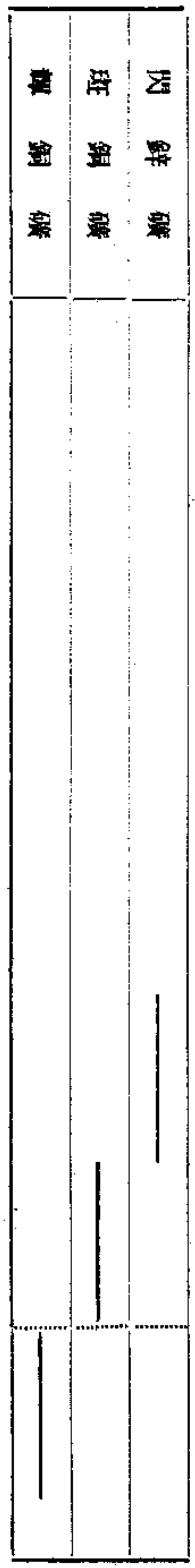
閃鋅礦　所採標本內之閃鋅礦，即不用顯微鏡亦可察出。若置于反光顯微鏡下，更可發見許多黃銅礦細點，散布于閃鋅礦之內，組成美麗之非混合結構（第九版第一圖），惟亦有黃銅礦之屑片，顯示交換閃鋅礦，証明一部黃銅礦似又稍較閃鋅礦爲後。

斑銅礦　此礦多呈細脈，含於黃銅礦內，當可爲交換黃銅礦之証（第九版第二圖），亦有少許交換閃鋅礦，其沉積自應較二礦物爲後。

輝銅礦　此礦在反光顯微鏡下，顯示均質性及藍白色澤，大抵含有多量之藍銅礦，呈溶合體。若以硝酸或綠化鐵滴于所製光面之上，每易生侵蝕解理或裂隙。最常見之交換礦物爲斑銅礦，多由邊緣侵向中心，或爲細脉包于斑銅礦之內，偶亦交換閃鋅礦，但較爲稀見耳，大抵屬次生礦物。輝銅礦與斑銅礦在礦體內含量俱甚微。

統計各礦物沉積之次序，則略如下表。





各礦物在礦體中之含量，則（一）毒砂（最多），（二）黃銅礦，（三）閃鋅礦，（四）錫石，（五）黃鐵礦，（六）斑銅礦，（七）輝銅礦（最少）。

六、普利公司砒礦

普利公司砒礦位於大順窿之東，距花崗岩稍遠，亦屬於桂陽。開礦者只知礦體內含有毒砂，經顯微鏡研究，始發見少許錫石。

毒砂　此礦爲礦體內最多之礦物，亦卽爲開礦者惟一有用之礦物。晶體多塊聚，若磨製光面置於反光顯微鏡下察之，則見晶面常帶有許多裂隙，且每爲黃鐵礦閃鋅礦等充塡（第九版第三圖）。

錫石　此礦在礦體內含量甚微，非用顯微鏡不易察出，恆顯示交換毒砂之跡。

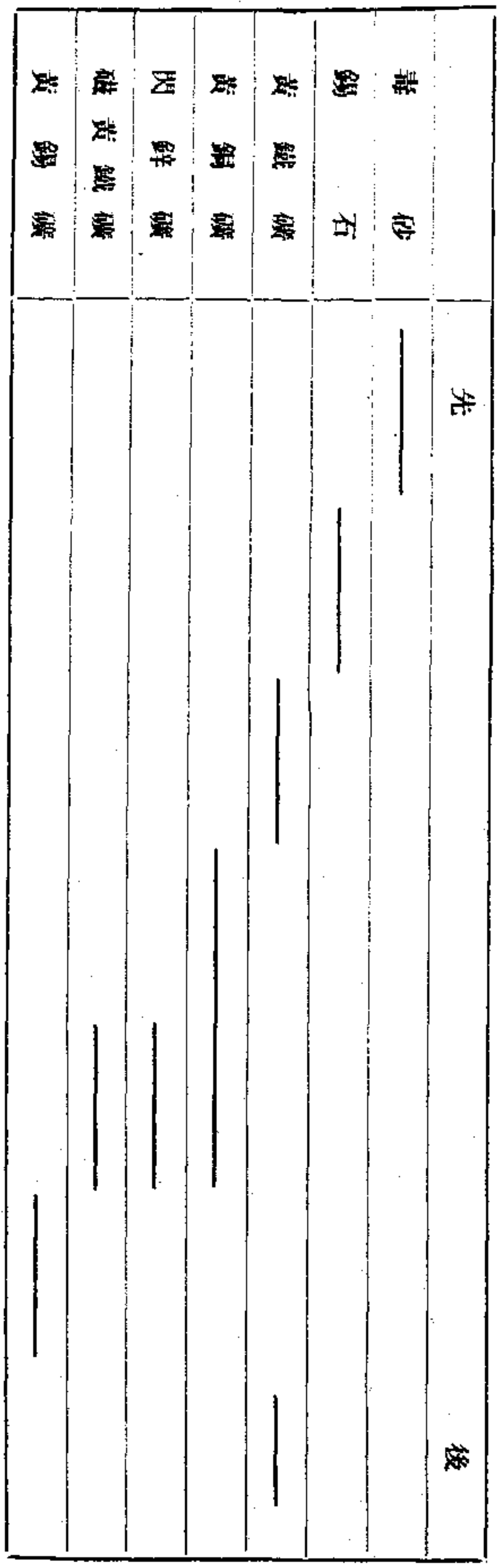
黃鐵礦　此礦每呈殘餘晶粒，包於黃銅礦之內，但亦有時爲細脈含於閃鋅礦，故大部黃鐵礦之沉積，雖較黃銅礦爲先，至少一小部沉積反較閃鋅礦爲後。

黃銅礦　晶體概爲塊狀，其被閃鋅礦與磁黃鐵礦之交換，頗爲明晰（第九版第四圖），且可見被黃錫礦交換之証。

黃錫礦　此礦僅爲少許屑片，含於黃銅礦與閃鋅礦之內，其沉積自應較閃鋅礦爲後。

閃鋅礦　此礦恆爲粗晶，其解理面極爲明晰，但亦有時呈微晶，在礦體中含量頗多。磨製之光面，每顯示含黃銅礦與磁黃鐵礦之細粒，組成美麗之非混合結構。

統計各礦物沉積之次序，則略如下表。



七、普利公司附近高溫閃鋅礦脈

此礦脈係普利公司開砒礦時，在礦洞內發現，因本地人不識爲何礦，未曾開採。現將所携標本磨製光面，置於顯微鏡下察之，則含有下列諸礦物。

閃鋅礦　礦脈全部幾悉爲此種礦物所組成，故標本之表面，槪呈黑色，他種礦物非藉顯微鏡不易察出。

磁黃鐵礦　此礦僅見數屑包於閃鋅礦之內，雖未發現交換閃鋅礦之証跡，其沉積似應較閃鋅礦稍後。

黃鐵礦　此礦含於閃鋅礦之中，亦只見數粒或呈細脈，故至少一部應較閃鋅礦沉積爲後。

黃銅礦　此礦沉積亦似較後於閃鋅礦，僅發見數條，含於閃鋅礦之內。

黃錫礦　此礦含量至微，其沉積應亦後於閃鋅礦。

八、大順廠附近錫石赤鐵礦體

大順鑪附近間有人開採赤鐵礦體，藉得少許錫石，礦體形狀極不規則，頗類似接觸交換礦床。以標本磨製光面察之，除赤鐵礦錫石外，兼含有少許黃鐵礦及毒砂，但赤鐵礦約占百分之八十以上。

附生礦石

一、北成鑪錫砒礦

北成鑪礦石之發育，可分爲二期。第一期約在毒砂錫石之後，黃銅礦沉積以前，第二期則在黃銅礦沉積以後，大部礦石屬於第二期，僅有一二種屬於第一期。矽酸鹽恆較硫化物沉結稍晚，乃爲此礦顯著之現象。

粒狀弗鎂礦　礦晶多呈長板狀，非用顯微鏡不易察出，平行於(001)面之反覆雙晶線，頗爲清晰。薄片在顯微鏡下概無色澤，故不顯多色性，屈折指數(Nm)近於一・六二二，其正號雙光軸性及大光軸角，皆可鑒定。干涉色每呈光帶第二組之紅色，平行於(010)或垂直於Z之剖面，X與反復雙晶線間之消光角，約爲三十度。

晶體在礦體內爲量尙多，往往於磨製之薄片中，見長方形之晶片頗夥，易於注意。

透輝石　此石有時呈巨大放射柱狀晶體（第四版第二圖），現灰綠色，硬度爲五。屈折指數(Nm)等於一・六九，在垂直於光軸之剖面，可証其正號之雙光軸性，(110)解理甚爲清晰，Z與C間之消光角爲三十八度。晶體恆被葉狀蛇紋石爲局部或全部之交換。其化學成分如左。

水分二・九二，矽氧四九・三七，鐵氧一・三二，鋁氧四・○七，鈣氧二三・一五，鎂氧一九・五三。晶體內所含之鋁氧達百分之四，最爲特異，此或爲含鋁透輝石或由於被葉狀蛇紋石交換所致，尙難斷定。

透角閃石　晶體現白細纖維狀，有時因太細之故，其光學性質不易鑒定，間亦有呈放射狀者。屈折指數爲一・六一，干涉色屬於光帶第二組之黃色，其負號雙光軸性及大光軸角，皆可鑒定。Z與C間之消光角爲十八度，有時底剖面顯示兩種方向之柱解理，相交約爲一百二十四度。

針柱石　晶體呈細柱狀，間有構成放射狀者。光性屬於負號單軸，往往因晶體太微，光性多不易鑒定。屈折指數(No)略等於一・五三，晶長爲負號，干涉色現光帶第一組之黃白色。晶體之發育，恆沿方解石解理與C晶軸平行，因之在直交聶谷爾下，顯示格狀組織，當針柱石發育極盛時，方解石有時全部被交換，生成球粒狀結構。此外又有一種晶體發育方法，即先將方解石變成土狀物質，次變爲透明針柱石，於薄片中可見各種方解石變針柱石之交換堦級。

針柱石在標本中多爲白色或稍帶綠色，薄片則每不顯色澤，但有時似微帶紫色，曾用化學試驗，証明晶體內確含有氯質。

鱗雲母　此礦多屬微小晶體，含於粒狀弗鎂礦或針柱石之細脈中。光性屬於負號雙軸及中等光軸角。是否爲鱗雲母或白雲母，尚未能完全決定，因礦體太小，含量又微，難於詳細鑒定也。

葉狀蛇紋石　晶體爲白綠色，有時呈巨大放射柱狀（第五版第一圖），硬度等於二。薄片恆不顯色澤，故無多色性，(010)及(001)解理頗完好，晶長爲正號，在平行於(001)或垂直於銳等分綫之剖面，負號雙晶軸性及小光軸角，皆可察出。屈折指數(Nm)等一・五六，在平行於010或光軸面之剖面，干涉色似近於光帶第二組之藍色，較平常之葉狀蛇紋石干涉色甚高，或者由於薄片太厚之故。X証明垂直於001解理，晶體大部似由透輝石變質而成，往往保存透輝石之假晶。其化學成分如左。

水分九・九四，鎂氧二五・〇二，矽氧五四・一九，鋁氧四・八六，鐵氧一・六五，鈣氧四・三一，鈉氧與鉀氧共〇・四八。

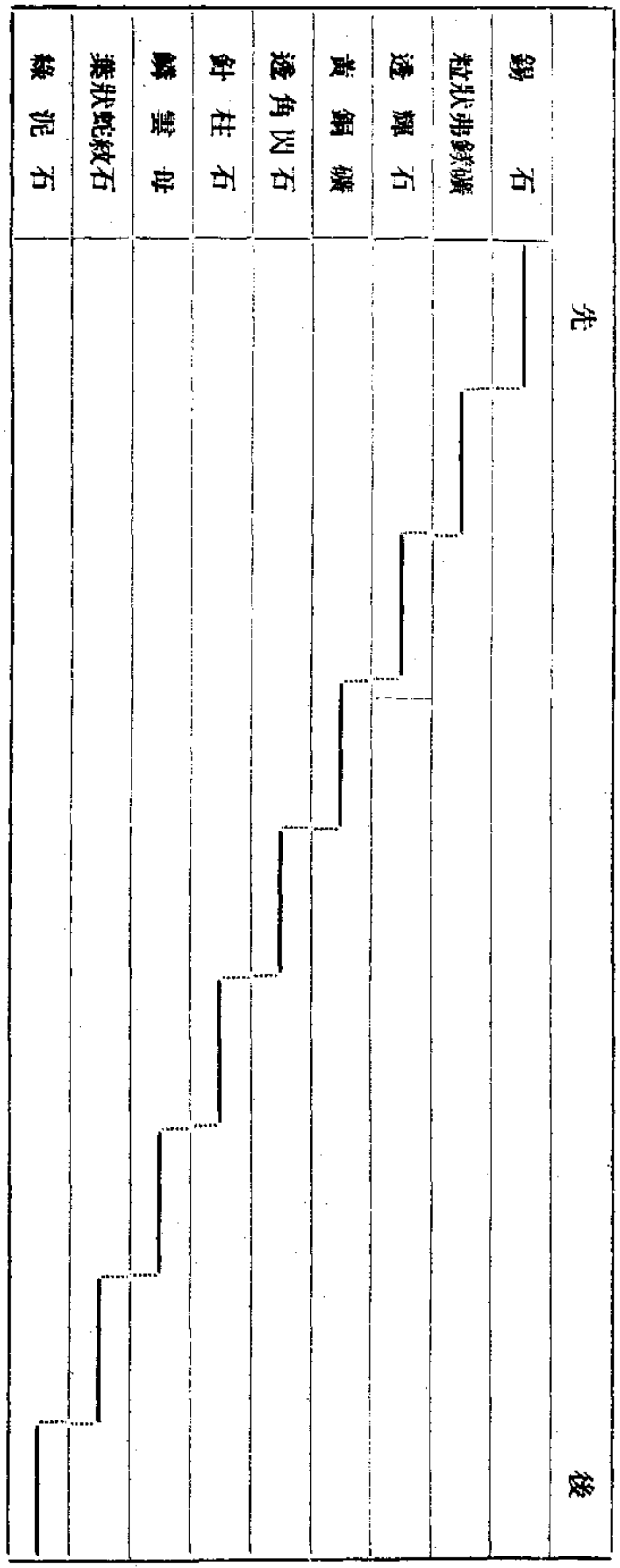
就中所含矽氧之量，較普通葉狀蛇紋石稍多，或者由於礦體內雜有柱石所致。

綠泥石　此石似爲鐵綠泥石，干涉色屬於光帶第一組之白色，解理頗清晰，晶長爲正號，光性則爲雙軸負號及中等光軸角。多色性頗強，y等於Z爲深綠色，X則近於無色。

文石　此石干涉色甚高，屈折指數各種方向相差頗多，光性屬負號雙光軸及小光軸角。

各礦石結晶之次序，較金屬礦物甚難確定，其重要原因，由於各礦石恆無連續接觸，故其相互之關係，遂不易明瞭。但亦有關係顯著者，如錫石之帶狀色澤組織，恆被粒狀弗鎂礦分割（第十版第一圖），及粒狀弗鎂礦晶體有時被黃銅礦裁切，而黃銅礦

則間有沿粒狀弗鎢礦裂隙發育者。透角閃石之柱晶，每橫穿黃銅礦晶體（第十版第二圖），針柱石之細針，則時生於透角閃石之柱晶內，鱗雲母之微晶，有時發育於針柱石之細脈中，他若針柱石鱗雲母等交換透輝石，皆極顯著。因之綜合各種情形，乃得左列結晶之次序



右表內錫石與黃銅礦雖非礦石，惟欲明瞭礦物與礦石沉積先後之關係，故亦列入。

二、川眼背砒礦

川眼背礦石結晶之關係，較北成鑪尤為曖昧，茲約略述之於左。

符山石　此石由顯微鏡下窺之，為柱狀晶體，微呈棕色，解理不甚清晰，但亦有時可見其平行於柱體。屈折指數(No)等於

一・七一五，干涉色爲光帶第一組之黃色，晶長屬負號，雖在磨製之剖面內，尙未得一中心光軸干涉圈，然此石之負號單光軸性，已可由偏光軸干涉圈証明。

中柱石　此石爲柱狀晶體，(100)及(110)解理尙稱淸晰（第十版第三圖），呈白綠色，光性屬負號單光軸。其化學成分如左。

矽氧三六・二六，鋁氧三四・〇二，鐵氧〇・九九，鈣氧一九・八〇，鈉氧六・九八，二氧化炭三・三〇，氯質一・四五。

鈣鋁石榴子石　此石在標本中呈紅棕色，晶體頗易辨認，硬度甚高。薄片無色或微現棕色，裂隙頗夥，呈顯著之光學異性。屈折指數(Nm)等於一・七五五，干涉色爲光帶第一組之白色，恆略呈帶狀組織，光性屬正號雙光軸及大光軸角，雙晶式似係十二面錐形。

石英　晶形頗不完整，其正號單光軸性，尙易鑒定，晶體之邊際，恆被透輝石交換。

透輝石　薄片在顯微鏡下無色澤，干涉色屬光帶第二組之紅黃色，Z與C間之消光角爲三十八度，光性爲正號雙光軸及大光軸角。屈折指數(Nm)稍小於一・七，光軸面平行於正號之晶長，柱解理頗淸晰。

鈉長石　多呈柱狀晶體，鈉長石雙晶線雖隱約可見，恆因受風化作用不甚淸晰。光性屬於正號雙光軸及大光軸角，屈折指數(Nm)小於石英。

矽灰石　晶體呈白色放射纖維狀，垂直於晶長或(100)解理之裂隙頗夥。屈折指數(Nm)等於一・六二，光軸面垂直於(100)解理或晶長，平行於光軸面之剖面，率顯示兩種解理方向(100)(001)，干涉色爲光帶第一組之黃色，X與C間之消光角爲三十四度，光性屬於負號雙光軸。

普通角閃石　此石在所磨之薄片內，僅有數粒，其光學性質不易完全鑒定。惟柱解理頗淸晰，多色性爲暗綠及黃綠色，亦甚顯著。

中性長石　除鈉長石之外，更見一種長石，其屈折指數似大於加拿大膠，光性亦爲正號雙光軸及大光軸角，茲定爲中性長

石。

鈣鎂鐵輝石　透輝石之外，有一種輝石，Z與(110)解理間之消光角近四十五度，屈折指數(Nm)略等一·七二，光性屬正號雙光軸及大光軸角，柱解理(110)頗清晰，干涉色爲光帶第二組之綠色。此石如非普通輝石即應屬於鈣鎂鐵輝石，但垂直於光軸之剖面，消光頗好，表示光之分散不多，故從後者。

針柱石　晶體呈塊狀圓粒，含有多量之包體，大抵屬炭質物。屈折指數(No)略近於一·五五，單光軸干涉圈不甚清晰，干涉色爲光帶第一組之白灰色，曾用化學試驗，証明其含有氯質。

葉狀蛇紋石　晶體呈長板狀，光性屬負號雙光軸，晶長則爲正號，光軸面平行於解理。

文石　晶體恆呈細脈含於鈣鋁石榴子石或他種礦物內，光性表現負號雙光軸及小光軸角。

各礦石之關係，較北成鑛尤欠明顯，惟符山石每包有矽灰石柱晶，而被其交換，中柱石亦每被鈣鎂鐵輝石普通角閃石及黃銅礦等（第十一版第一圖）交換，以致時含鈣鎂鐵輝石晶體。鈣鋁石榴子石之裂隙，有時被透輝石及石英充塡，但石英又間被鈣鎂鐵輝石交換，或透輝石分割，及交換鈉長石。更有中性長石被鈣鎂鐵輝石及普通角閃石交換，矽灰石則恆被透輝石交換，以致輝石每包有矽灰石殘晶，同時透輝石又被針柱石交換，鈣鎂鐵輝石亦有時被針柱石交換，而針柱石則似有矽灰石切割之跡。故矽灰石之發育，似可分兩期，一在透輝石結晶之先，一在針柱石之後。又鈣鎂鐵輝石每含有黃銅礦細脈，表示黃銅礦之沉積，應在輝石之後。茲爲顯示各礦石約略結晶之次序起見，重表列於左。

1. 符山石(最先)
2. 中柱石
3. 鈣鋁石榴子石
4. 鈉長石
5. 中性長石
6. 石英
7. 矽灰石
8. 透輝石
9. 鈣鎂鐵輝石
10. 針柱石
11. 矽灰石
12. 普通角閃石
13. 黃銅礦
14. 葉狀蛇紋石
15. 文石（最後）

右表中葉狀蛇紋石及文石，大抵屬於次生礦物，與砒礦之生成，或無直接關係。

三、倒石湖錫砒礦

倒石湖之礦石，種類繁多，爲各礦冠，茲試述之於左。

中柱石　在顯微鏡下解理頗清晰，光性屬於負號單光軸，有時局部變爲絹雲母，複屈折差數略近於〇・〇二五。

弗石　色澤呈白色或稍帶紅色，平行於八面體之解理頗清晰，晶面不甚完整，多爲粒狀，含量甚夥，光面屬於均質，屈折指數爲負號，小於加拿大膠。

鐵電氣石　晶體爲長柱狀（第六版第二圖），多色性Z爲藍色，X爲暗紫灰色，吸收性Z大於X，柱晶兩端之藍色，恆呈帶狀組織。干涉色達於光帶第三組，光性屬於單軸負號。

石榴子石　此石呈棕色而微綠，置於顯微鏡直交聶各爾下，顯示複屈折頗清晰，平行於十二面體之雙晶亦常見，更含有許多裂隙。雖光學性質未加詳細鑒定，大抵屬於鈣鋁石榴子石類。

燐灰石　此石在磨製之薄片中，僅發見數粒，其屈折指數甚高，複屈折差數則頗低。

透輝石　晶體呈綠色長柱狀或粒狀，解理頗清晰。光性屬正號雙光軸及大光軸角，Z與C間之消光角略近四十五度，故此透輝石又近鈣鎂輝石。

普通角閃石　晶體呈柱狀及放射狀，柱解理(110)頗清晰，底剖面每顯示兩種方向之解理，其交角構成一百二十四度。多色性Z爲藍色，y爲綠色，X爲黃色，吸收性則X小於y，又y小於Z。屈折指數(Nm)等於一・六八，Z與C間之消光角等於二十五度，光性屬於負號雙光軸及大光軸角。

透角閃石　晶體呈纖維狀及細柱狀，比重略等於三，標本現暗綠色，薄片無色，或屬於透角閃石與陽起石之變種。柱解理頗清晰，底剖面表現相交約一百二十四度之兩種解理方向，多色性不易察出，屈折指數(Nm)等於一・六二，Z與C間之消光角近於十

八度，干涉色爲光帶第二組之綠色，垂直於X之剖面，干涉色則屬光帶第一組之黃色，光軸面平行於正號晶長，光性屬於負號雙光軸及大光軸角。其化學成分如左。

水份一．四三，矽氧五〇．四七，鐵氧一．一七，鋁氧一四．五三，鈣氧一〇．九七，鎂氧二〇．五七。

白雲母　晶體極爲細微，構成脈形，生於針柱石內。光性屬於負號雙光軸及中等光軸角，頗疑屬於鱗雲母，惜晶體太小不易詳確鑒定。

石英　僅於一塊標本內發見石英粒頗夥，其正號單光軸性，皆易於鑒別。

尖晶石　晶體爲黃色，僅在顯微鏡下顯示數粒，呈均質性，屈折指數頗高。

針柱石　晶體呈塊狀，屈折指數較加拿大膠稍高，干涉色爲光帶第一組之紅黃色，光性不易鑒定。

鱗雲母　此石有兩種，一種晶體呈短柱狀及不規則形態，(001)解理頗清晰，且時見假六方底片，多色性X無色Z微現綠色，因2v等於零，故在顯微鏡下顯示負號單光軸性，銳光軸角等分線近乎垂直於(001)。曾用化學試驗，証明含有鋰質。更有一種爲負號雙光軸性，及微小光軸角，屈折指數(Nm)等於一．五九，複屈折頗強，多色性Y爲白色而微綠，Z爲綠色，X爲黃色，亦曾用化學試驗，証明其含有鋰質。

鋰電氣石　晶體僅有數粒，其是否含有鋰質，雖未能用化學方法試驗，但其光學性質與大順溝已証明含鋰之電氣石頗相似，故亦暫稱之爲鋰電氣石。多色性頗強，X無色，Z爲藍色，吸收性X小於Z，干涉色爲光帶第二組之藍色，光性則屬負號單光軸。

葉狀蛇紋石　晶體爲柱狀，複屈折差數略等於〇．〇〇五，解理頗清晰，橫裂痕甚夥，晶長屬於正號。

綠泥石　晶粒爲塊狀，複屈折差數幾等於零，大部由於輝石或角閃石變質所致。

各礦石關係明顯其結晶次序較易推定者，爲中柱石之交換毒砂，及弗石細脈分割中柱石，而此種細脈有時更被普通角閃石橫

穿，且普通角閃石柱晶之發育，間沿弗石之裂隙，鐵電氣石往往含弗石殘粒，或發育於弗石晶體之接觸帶，表示鐵電氣石結晶後於弗石，又石榴子石亦每含弗石殘餘圓粒。透輝石之發育，則時沿石榴子石裂隙，黃銅礦每伸入於透輝石解理或裂隙，而構成細脈，透角閃石柱晶交錯於黃銅礦內（第十一版第二圖），恰如長石在輝石岩基構成之輝綠岩組織，但透角閃石遇毒砂接觸，則不顯示交換，此蓋由於「選擇交換」之特性所致，黃銅礦有時含石英與弗石脈，不惟表示石英與弗石皆較黃銅礦結晶爲晚，且表示弗石之發育，約有兩期。透角閃石柱晶恆排列於弗石或針柱石石基之內，故透角閃石之結晶，自應後於針柱石，更有時可見以毒砂爲核心，而透角閃石柱晶放射於其四周，鱗雲母晶體時分割黃銅礦（第十一版第三圖）。更見一礦脈從脈之邊際向中心，現一美麗之自然次序（第六版第二圖），爲毒砂弗石鐵電氣石黃銅礦鱗雲母等，鋰電氣石與他礦石之關係，不甚明瞭，但頗似結晶後於鱗雲母。茲將各礦石結晶之次序，重表列於左。

一、中柱石　二、弗石　三、鐵電氣石　四、石榴子石　五、燐灰石　六、透輝石　七、普通角閃石　八、黃銅礦　九、白雲母　十、石英　十一、尖晶石　十二、針柱石　十三、弗石　十四、透角閃石　十五、鱗雲母　十六、鋰電氣石　十七、葉狀蛇紋石　十八、綠泥石。

右表中黃銅礦雖非礦石，但欲顯示黃銅礦與各礦石之關係，故亦列入。

四、大順隆錫砒礦

大順隆之礦石，種類甚少，最要者只有兩種如左。

鋰電氣石　晶體爲細微針柱狀或呈放射狀，多色性Z淺藍色，X無色，吸收性Z大于X，屈折指數(No)等於一·六三八。其化學成分如左。

水分九·一五，矽氧二六·三七，鐵氧八·五五，鋁氧三五·五一，鈣氧二·六五，鎂氧六·一六，鈉氧五·六四，鋰氧〇·二〇，硼氧七·四七。

細察化學成分似乎頗近于鎂電氣石，但光學性質則近于鋰電氣石，由此蓋可証明雖含鋰氧小至千分之二，而礦物之光學性質，卽能屬於鋰電氣石。

弗石　晶體呈白色，間帶紫色，平行於八面體之解理頗清晰。

五、普利公司砒礦

石英　晶體內包有多量不透明含體，且有時沿一定方向排列。光性屬于正號單軸，亦可鑒定。

重石　晶體爲錐形，呈白色，在顯微鏡下僅發見數粒，屈折指數大于一•七七，最大屈折差數略近于〇•〇一六，光性屬于正號單光軸。曾用化學試驗，証明含有鎢質。

弗石　晶體微帶綠色，解理頗清晰，有時包有含體頗夥。

鱗雲母　晶體呈短片，多色性微顯綠色及無色，2v等於零，故在顯微鏡下表示負號單軸光性。

綠泥石　晶體呈棕色纖維狀，光軸面平行于正號晶長，光性屬于負號雙光軸及小光軸角，干涉色爲光帶第一組之黃色。

各礦石結晶之次序，(一)石英，(二)重石，(三)弗石，(四)鱗雲母，(五)綠泥石。

錫砒圓筒礦床構成之方法

細察北成隴大順隴一帶之圓筒狀錫砒礦，最先沉積之礦物，如毒砂錫石等，恆構成圓筒之外部，近中心則漸多黃銅礦及矽酸鹽礦物，頗似圓筒之生成，先由沉積較早之礦物，構成圓形外輪，繼由沉積較晚之礦物，充填輪內。現在所難推定者，爲構生外輪時，礦液抑沿圓心上升，再向周圍沉積歟，或直接先侵入筒之外輪歟。又礦脈生成之先導爲裂縫，不規則礦體之構形，由於逐次交換，而圓筒發育之導線爲何，此更難解者也。但觀礦體內恆含有空隙，尙未充填，而空隙之四周，則滿布完好之晶體，此空隙應存于礦液未至之先，頗可推証，且圓筒礦體之本身，亦每灣曲增減，極無規則，顯示礦液前進時，確尋圍岩最薄弱易侵之處而交換，或有時遇空隙大處則充填，但交換當爲主要之成礦方法。

錫砒圓筒礦在礦床學上之分類

錫砒礦床呈圓筒狀者，世界最著之區域，爲湖南廣西越南暹羅馬來半島一帶。而馬來半島之錫礦，雖經地質學者詳加研究，但對于此等礦在礦床學上應列于何類，皆未深切研討。美國著名經濟地質學者林葛禮氏，曾將此種圓筒狀之錫礦，暫屬于高溫礦床，而表示有所疑慮。玆考此種錫砒礦如在湖南所見者，恆形式上與高溫閃鋅礦脈極接近或連屬，且有時距花崗岩露頭稍遠，達四五里，以之列入高溫礦床，自可謂有相當理由。惟所含礦石如矽灰石透輝石透角閃石等，大部屬于接觸變質類，而由礦物爲圓形之排列，因而構成筒狀組織，亦爲接觸變質礦床之特性，故就此方面立論，似又應屬于接觸變質礦床。但礦石在接觸變質類，每較成礦礦物沉積爲先，而圓筒錫砒礦之成礦礦物，如毒砂黃銅礦等，則反較大部礦石沉積爲早，普通礦床內，礦石甚少交換硫化物，而此錫砒礦床，則黃銅礦恆被各種礦石交換。凡此種種，皆顯示圓筒錫砒礦在礦床學中自具有特異之性質，以之強列入高溫礦床，或接觸變質礦床，似皆非所宜，最好專別爲一類，位于高溫礦床與變質礦床之間，玆名之爲錫筒礦床。

礦量及礦業

錫砒兼產之礦，首推北成窿，現爲順成公司開採，大順窿次之，現爲鴻泰公司開採，其餘若倒石湖光裕窿等處，雖從前亦曾產多量之錫砒，但現皆停採，僅尙有三五工人，就舊礦洞口採取殘餘之礦砂少許，出賣而已。專產砒石之礦，以普利公司最著，川眼背次之，橋下窿之宏益公司現已停工。

各礦體雖大致呈圓筒狀，但體積之漲縮，極無一定，含礦之貧富，亦恆隨地而異，且主支之分合，更難預料，因之估計礦量，事實上頗感困難，如按已採礦體之情形，勉強推算，恐亦無裨益于實際。故與其表示遺留礦量以不確當之數目，何如就已往開採之狀況，參考礦床之成因，約略推斷各礦將來之希望。根據是說，現可斷言者，礦囊應愈深愈小亦愈少，惟共生之礦石，多係高溫沉積，故各礦礦囊愈深愈小愈少之變遷應甚緩。現在各礦僅開採深至數十公尺以達一二百公尺，其下如再深至一二百公尺，礦體似不至罄盡，所可慮者礦體或更將縮減耳。

錫砒各礦之產額，向無確實統計，其原因由于礦商自己既鮮系統之記載，又往往不欲以詳數告人。但約路估計亦可知其梗概，大抵北成窿順成公司每年約可產純錫二十五噸，砒石包括川眼背在內，每年約可產二百八十噸，大順窿鴻泰公司每年約可產純錫六七噸，砒石包括普利公司在內，每年約可產百餘噸。北成窿所產之錫砒，多用人工挑至相距十里之羊隔洲，再裝船下春水入湘江，運銷于衡陽長沙。大順窿錫砒，則恆用人工挑至峽水口，再裝船沿春水運至相距二十五里之白沙鎮　，或直接運往衡陽出售。

北成窿大順窿一帶錫砒鑛之採煉法，雖皆沿中國舊式成法，然用費較泰西新法爲省，小規模之經營，亦頗足用，且亦甚有系統，實有記載之價值，試分述之于左。（此節大部根據田奇瓗君報告）

（一）採砂　採礦本地人稱謂採砂，窿洞內採砂之處所則稱謂莊，每一窿可分數莊，各冠以天地人等字，如天字號莊地字號莊等。工人分鑿砂運砂兩種，悉屬包工制，工作晝夜不息。鑿砂工人又分爲若干班，每班每人以鑽兩炮眼爲度，鑽好後以藥炸之，第一班卽出莊，第二班繼續入場，首將第一班炸下之鑛砂鑛石搬至莊外，是謂淸莊，再開始鑽眼放炮，第三班亦如之。至各班工作皆完之後，始由運砂工人將所炸下之鑛砂鑛石，悉數運至窿口外，秤其重量，付與運費，且令人將鑛砂鑛石分別剔出，再秤剔出之鑛砂，以便付與鑿砂工人工資。若遇鑛脈窄狹時，則以開鑿公尺體積計算，惟所剔出之鑛砂，仍可照旺砂時減半給價，付與鑿砂工人，又各工人飲食概歸自備。

（二）選砂　鑛砂須搥成徑寸之塊，始入煆灶煆灰，夾有鑛石者，則用手剔選，或在水中篩洗，悉屬包工制。

（三）煆灰　因毒砂與錫石共生，須將砒份燻出，始能煉錫。煆灶（第二版第二圖）用火磚與亂石砌成，每十四灶爲一排，灶分前後兩部，其底有小煙道相通，每灶可盛鑛砂七十斤，用木炭七斤及煤十七斤相隔裝入灶之前部，晨間升火後，將火門封閉，養化砒則經過煙道而凝聚于灶之後部，卽爲砒灰。煆一晝夜之後，翌晨卽須換灶，殘餘未化之渣，謂之灶屎，大部爲錫石及他不易揮熔之鑛物。煆灶每隔十日出灰一次，每次每灶一排約可得灰三千斤，約可煆礦砂一萬斤，故鑛砂之煆灰率，約爲百分之三十

，煆灶工人則係日工制。

（四）洗渣（第二版第一圖）　灶屎自煆灶取出後，用水碓舂碎，再用十分一吋徑孔之篩篩過，遺留篩內之粗砂，復歸水碓舂搗，過篩之細粒，即移入淘洗池冲洗。合三池爲一座，首引水入第一池，用耙攪拌，將較小之錫粒及雜石繼入第二第三池，亦同樣攪拌之，第一池所沉積之砂，取出置于密篾篩中，浸於水內篩洗，去其雜石，是謂淀砂，留于篩內之錫砂，名曰銅生。以銅生和黃泥做餅，入煆灶中復煆，再取出磨碎，重經陶洗淀砂各手續，如此所得之錫砂，謂之上爐砂，即用以煉錫。淀砂時用手剔去之細砂末中，因尚含有錫砂，乃移置于三合土做成之斜臼上，臼下有儲水小池，工人用竹製之小排鈎激水洗砂，則錫砂沉于臼底，是謂漓塵，如此所得之錫砂，可滲入銅生中復煆。凡由第一池所得之上爐砂，謂之第一道砂，其遺留于第二第三池之雜砂，亦移入第一池，復經冲洗淀砂漓塵復煆手續所得之上爐砂，謂之第二道砂，做第二道砂時，遺留于第二池之雜砂，又依樣選洗，是爲第三道砂，如此遞移，至第八道砂爲止，所用工人概取包工制。

（五）煉錫　上爐砂每百斤和香灰二斤麵灰半斤加水使成餬狀，藉以免升火鼓風時錫砂之揮散。煉時先將松炭加入爐內，升火之後，始將餬狀錫砂用鐵瓢舀入約二三斤而止，復加松炭于其上，待松炭燃燒極盛時，又舀入錫砂，再蓋松炭，如此循環遞加，至錫砂煉盡爲止，大約開煉一小時之久，錫砂即因炭化作用而還原，錫汁自爐門流出。火爐用磚砌成，名曰通天爐，爲長方形，頂有圓孔，徑約一尺二寸，直通爐底，故爐腹爲圓筒狀，一側備有風箱，他側近底處有爐門，錫汁從此流出，聚于圓鍋內。鍋爲鐵製，上塗黃泥及木炭末，錫汁流入鍋內，須時時散播炭末于其上，以防養化，俟鍋內聚集稍多時，用鐵瓢舀入砂土製之模型中，待其稍冷，不純之物上浮，乃用鐵鏟割去，再冷便成錫條，每條重由五十斤至五十五六斤不等。錫砂煉錫成數，頭道砂六成，二道砂以下五成，煉錫亦用包工制，一晝夜約可煉純錫一千三百斤。

（六）燻砒　砒灶用火磚砌成（第二版第四圖），灶上用黃泥做成圓頂，灶內用無烟煤升火後，將砒灰散布于圓頂上，以鐵鍋覆之，鍋內塗細砂一層，厚約三四分，劃成四寸見方之格狀。覆鍋後砒灰受熱昇騰凝聚于鍋內，如是繼續燻煉，每晝夜添砒灰二

次，加煤二次，至四十晝夜之後，謂之一班，即可停息。一班一鍋之內，約可結砒二百斤，取下後依照塗于鍋內砂層上所劃之方格，搥成四寸見方之塊，每塊厚約二三寸，色爲淡黃色，裝于圓柱形之木桶內。砒灰之燻砒率，上等灰可燻八成，較劣之灰，僅能燻四成。

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ALUNITE DEPOSITS OF LÜCHIANG DISTRICT, CENTRAL ANHUI

BY Y. C. CHENG AND K. CHERN

With 8 plates and 4 text figures

CONTENTS

I. INTRODUCTION

In October of 1933, we were sent by the Geological Survey of China to investigate the alunite deposits of Luchiang district in central Anhui. We remained there for eight days, during which a topographical and geological map in the scale of 1 to 20,000 was made. The surveyed area is 7.5 km. long from east to west and is about 4 km. broad, it includes all localities where alumstone is being worked or has been exploited.

There are altogether three large alumstone deposits in China, viz., Pingying in S. E. Chekiang, Luchiang in central Anhui, and Futing in N. E. Fukien. Their origin as well as geological occurrence are very similar to each other. According to the present knowledge, the Luchiang deposit is of importance only next to Pingyang, though in reserve and production the former is far less in amount than the latter.

Owing to the absence of K. Chern, the microscopic study of the rock samples was chiefly done by Y. C. Cheng and the report is also written by him, hence he is responsible for any mistakes that may occur in this paper.

The writers are deeply indebted to Prof. C. Y. Hsieh for his valuable suggestions and criticisms regarding the microscopic study of the alumstone as well as to the origin of the depósits. Mr. S. Y. Hsiung, chemist to the Survey, has kindly undertaken the chemical analysis of the specimens and to whom we are under great oligations.

II. LOCATION AND TOPOGRAPHY

This deposit is situated on the border of a mountainous region about 80 km. northeast of Huaining, the capital of the province, and 25 km. southeast of the district city (see Fig. 1). The alunitized beds have an east-west extension about 3 km., i. e., from Shihtsaoling (石曹嶺) to Kuanyinting (觀音頂), and a similar extension in a north-south direction, that is from Kueishan (龜山) to Shiachiayuantze (夏家院子). But only a few thin layers are rich enough to serve as ores or alumstone for the manufacture of alum. It is on the valley slopes closely neighboring such richly alunitized beds that the two well known populous and prosperous localities, Tafanshan (大礬山) and Hsiaofanshan (小礬山) which mean large alum mountain and small alum mountain respectively in the exact sense—have grown up. In these two towns a great number of alum-roasting kilns (Pl. IV, Fig. 3) are present.

The alum produced is first carried by coolies to Chiukow (缺口), a small town situated 8 km. north of Tafanshan and along the south bank of Sichiang River (西江), and then it is loaded in the small boats and brought either up stream to Luchiang and other cities or down stream though a water transportation of 70 km. to the mouth of the river. From here it is further navigated eastward in the Yangtze River for 60 km. to Wuhu, where the alum is repacked and then distributed to different ports along the river. According to the informations of the natives. Sichiang River is navigable for small boats all the year round and for steam boats in the wet season only, hence the communication facilities of this alum-producing center is comparatively convenient. A small part of the alum is carried 15 km. westward from Hsiaofanshan to Luchangho (羅昌河), and then brought to different neighboring towns or cities by small boats.

Generally speaking, the region is a maturely dissected mountainous country of moderate relief, with more or less flat tops, gentle slopes and broad and open intervening valleys. But in several localities, for instance, in the valley east of

Pichialao (畢家老), this mature landform is further sculptured by canyon-like young valleys, which are evidently of recent development and may still grow in the full speed at present. Hence two physiographic stages at least, can be distinguished from the landform observed.

The summits of the hills are usually 200 m. or more above the neighboring flat ground surface, while the highest one, viz., the top of Chuntzeshan (鍾子山), attains a local altitude of 350 meters. As all the rock-strata in this region are only slightly disturbed and have a general dip toward west or northwest, the land forms are consequently more regular, with ridges frequently parallel to the strikes of the

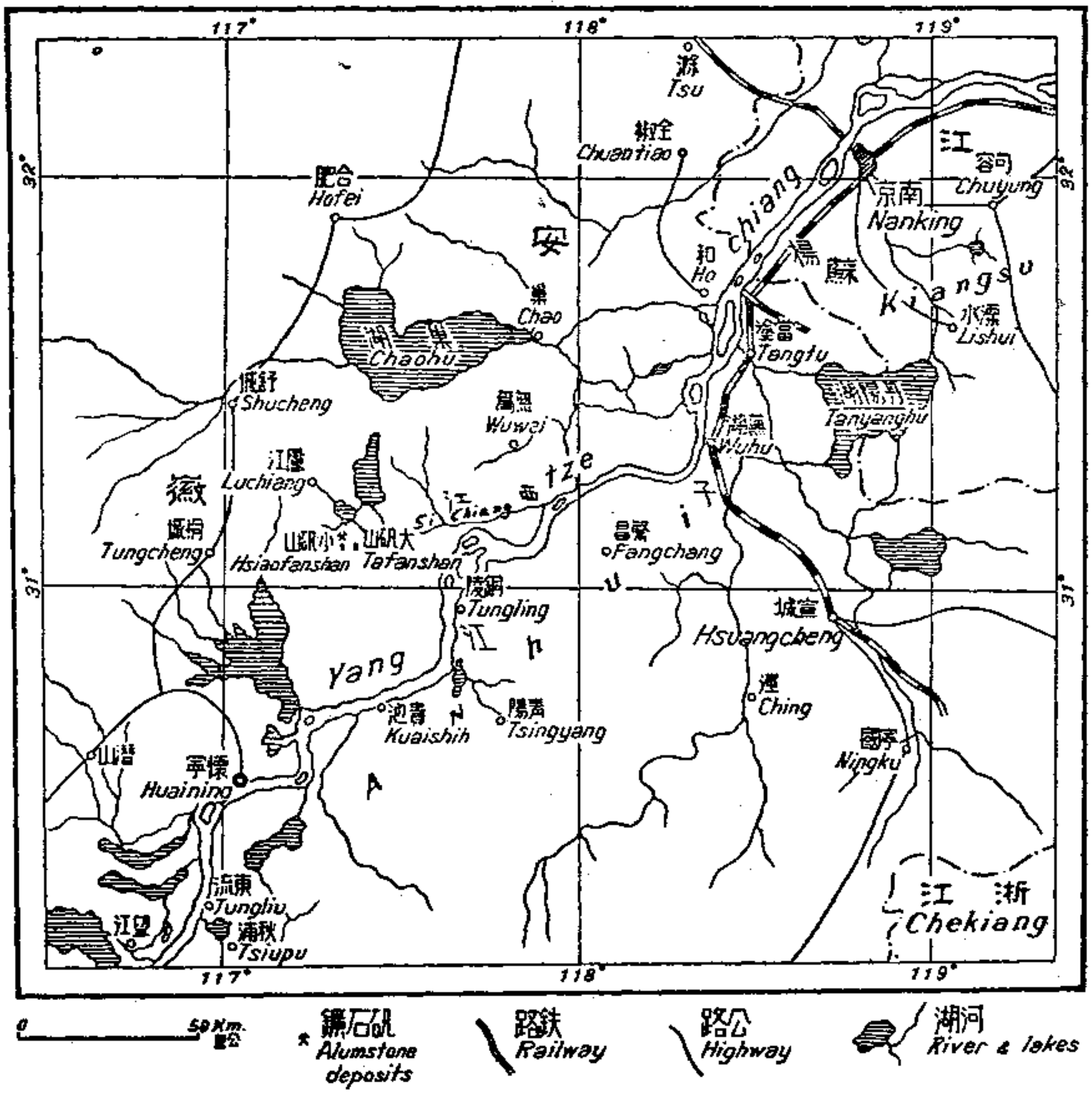

Fig. 1. A map showing the location of Luchiang alumstone deposits

beds, and dip slopes and hogbacks are of common occurrence. The drainage pattern is of a trellis type with subsequent and consequent valleys intersecting each other at right angles.

Owing to the hard and compact nature of the rocks, the quartzite of the Jurassic Chuntzeshan formation usually forms hills of higher altitude and steeper slopes, the tops of which reach a local elevation of 300 meters or more. The topography of the volcanic series is generally characterized by lower altitude, flater tops and gentler slopes, but those composed of the silicified variety may attain an elevation of 200 to 260 meters above the adjacent plain. Small rolling hills with wide intervening valleys are the characteristic landform for the places where intrusive bodies are present.

III. STRATIGRAPHY AND STRUCTURE

Both the stratigraphy and the structure of the Fanshan area is rather simple. A quartzite series, probably of Jurassic age and having a thickness of about 700 m. is overlain unconformably by a thick and extensive volcanic series, the former is gently folded while the latter is only tilted or warped. Owing to the absence of fossils, it is impossible to make a detailed and accurate stratigraphical correlation with the neighboring region. The formations so far recognized are described as follows in ascending order.

A. CHUNTZESHAN SERIES

In the south-eastern part of the surveyed area, there exist several rocky and rugged hills such as Chuntzeshan (see Pl. III, Fig. 4), Tienkuangshan (天光山) and others, which are composed mainly of a monotonous series of massive quartzite. The rock is greyish white in color, and is very fine and compact. Sometimes it is very similar to the silicified tuff of the overlying volcanic series that cropped out to the west of the hills just mentioned, but the latter can be distinguished from the former by its abundance of vesicles. The basal part of this series is not seen and therefore its total thickness cannot be measured; the exposed part estimated being about 700 meters. It is most probably to be correlated with the Tsuhsiatung quartzite of Nanking[1] and the uppermost part of Tsaishih formation of Tangtu district[2] for the following three reasons:

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[1] C. Y. Hsieh, Geology of Chunshan and its Bearing on the Supply of Artesian Water in Nanking, Bull. Geol. Soc. China, Vol. VII, No. 2, 1928.

C. Y. Hsieh and others, Notes on the Artesian Wells in Nanking, Bull. Geol. Surv. China, No. 16, 1931.

[2] C. Y. Hsieh and others: Geology of the Iron Deposits of the Lower Yangtze, Mem. Geol. Surv. China, Ser. A. No 13, 1935 pp. 8-10 (English).

1) Its lithological character is very similar to these two formations just mentioned.

2) As in the case of Tsaishih formation, the Chuntzeshan formation is also lying unconformably under a volcanic series, probably of Cretaceous age.

3) The hills of the Fanshan area actually constitute the southern limb of the west extension of the Ningwu syncline[1], which formed an elongated and open basin at the time of Cretaceous volcanic eruption. So the age of the Chuntzeshan formation is most probably the same as that of Tsuhsiatung formation, the Jurassic age of the latter has been confirmed by palæontological evidence.

Inasmuch as its exact stratigraphic correlation can not be made with Nanking area and other localities a new name may be herewith proposed. Thus, this series is now called Chuntzeshan formation named after the mountain Chuntzeshan where it is well developed and represented.

B. VOLCANIC SERIES

This volcanic series occupies a larger part of the area investigated. As shown in Pl. I and Pl. II it is evidently lying unconformably upon the Chuntzeshan series. The directions and angles of the dip of these two series change suddenly along their contact line. As in the case of Tangtu, this volcanic formation can be correlated with the Kienteh formation of Chekiang[2], Wuyi formation of Chekiang-Kiangsi-Fukien border[3], and the volcanic series near Nanking that has been studied in great detail by Messrs. Yih and Yu[4]. Therefore, it belongs to Cretaceous.

It consists of variegated volcanic rocks[5] of different composition, ranging from andesite, andesitic tuff, trachyte, trachytic tuff, breccia, to tuffaceous sandstone, but the tuff rock being the most abundant variety. Owing to their extensive alteration, the names of these rocks are usually difficult to determine. This renders microscopic study of the rock samples a hard task.

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[1] C. Y. Hsieh and others: Geology of the Iron Deposits of the Lower Yangtze, Mem. Geol. Surv. China, Ser. A. No 13, 1935 p. 13 (English).

[2] Liu and Chao: Geology of Western Chekiang, Bull. Geol. Surv. China, No. 9, 1927.

[3] Wang and Li: Geological Reconnaissance along the Nanking-Nanping Section of the Projected Railway Line from Nanking to Canton, Bull. Geol. Surv. China, No. 14, 1930.

[4] Yih and Yu: The Igneous Geology of Nanking Hills, Mon. Nat. Inst. of Geol., Acad. Sinica, Ser. B, Vol. 1, 1934.

[5] Among the specimens collected, 3 of them have a composition similar to rhyolite, but cannot be determined accurately owing to the extensive alteration they have undergone.

In addition to the weathering caused by common atmospheric agents and the ground-water action, most of the rocks have been extensively altered by hydrothermal action, which will be discussed in some detail in a later chapter. The degree of alteration suffered by various rocks often varies with their original lithological composition; a great many of complicated rocks are thus produced. The silicified ones are very hard and compact, while those altered by the processes other than silicification are rather soft and even loose. As to the origin of these alterations, it may be safely attributed to the hydrothermal effect that produced not long after the granitic and dioritic intrusions.

The sequence of this whole formation is not easily traceable so a detailed columnar section is rather difficult to draw. But based upon what has been observed in the field and with the help of microscopic study of some specimens, we may tabulate the general succession in descending order as follows (refer to Pl. II).

(24) Greyish white trachytic tuff and trachyte porphyry, upper part not exposed. 80 m. thick

(23) Altered agglomerate and coarse volcanic breccia of greyish and pinkish white color, occasionally alunitized and silicified. 50-60 m

(22) Greyish white tuff, trachytic tuff and trachyte ... etc., all being partly alunitized and silicified, but the alunite content is rather low. 50-60 m

(21) Alumstone bed or alunite-rock of various color—highly alunitized tuffs, trachyte . . . etc. (the sixth alumstone layer). 0-40 m

(20) Purple and white banded trachyte (R. No. 5334), slightly alunitized and showing distinct fluidal structures. 5-10 m

(19) White silicified tuff, fine and compact, but vesicular. 30-90 m

(18) Altered agglomerate of light color, occasionally alunitized and silicified. 15 m±

(17) Alunitized and silicified tuff, trachytic tuff and trachyte, etc., the color ranges from greyish white to purplish grey, and the alunite content is rather low. 60 m±

(16) Alunite-rock, chiefly an alunitized trachyte porphyry (the fifth alumstone layer). 0-5 m

(15) Light colored alunitized and silicified tuff, trachyte . . . etc. 100 m±

(14) Alunite-rock—alunitized trachytic tuff and tuff, usually white to light grey in color (the fourth alumstone layer). 0-8 m

(13) White to light grey alunitized and silicified tuff, trachyte, etc., the alunite content is very low. 100 m±

(12) Purple- and greyish-white-laminated tuffaceous sandstone, slightly alunitized (R. No. 5347). 30 m ±
(11) Light colored alunitized and silicified tuff, trachytic tuff . . . etc. 30 m.
(10) Alumstone—alunitized fine tuff, breccia, trachytic tuff, and trachyte porphyry, etc. (the third alumstone layer). 30-50 m.
(9) Alunitized tuff, trachytic tuff, etc. 100 m.
(8) Purple to greyish white tuffaceous sandstone, slightly alunitized. 40 m.
(7) Alunite-rock—alunitized tuff and tuff sandstone (the second alumstone layer). 0-5 m.
(6) Purple to greyish white tuffaceous sandstone, slightly alunitized. 40 m ±
(5) White silicified tuff, compact and quartzite-like, but vesicular, often slightly alunitized. 40 m ±
(4) Alunite-rock—alunitized trachytic tuff, agglomerate, etc. (the first alumstone layer). 0-10 m.
(3) White silicified fine tuff, versicular and hard, occasionally alunitized. 220 m.
(2) Trachytic tuff and trachyte porphyry, strongly altered. 100 m.
(1) Andesitic tuff and andesite porphyry. 300 m.
Total thickness of exposure: 1500 m ±.

In the above table, the first and second layers, i. e., (1) and (2), crop out to the east of Luchiawu (盧家凹); the third one and up to the eighth layer are mainly found at the hill of Tungshan and their southern extension has been traced as far as west of Shihtsaoling; the outcrop of the 9th to 14th horizon can be seen in the regions between Tafanshan and the summit of Chiaotzeting (轎子頂); the 15th to 21th stratum crop out from Chiaotzeting westward to Hsiaofanshan; from the 22th layer upward, they are chiefly found in the area to the west of Hsiaofanshan. Whether or not there is any strike fault in the upper part of this formation so as to make repetition of the beds is not certain. More detailed investigation of the volcanic series may be able to settle this problem.

As shown in the above table, the eruption of lava and pyroclastic rocks gradually changed its composition from basic to acid. This corresponds to the general succession of the Cretaceous volcanic series of south-eastern China so far investigated. Based upon this criterion, this formation can be arbitrarily subdivided into two parts; an upper part consists mainly of fine tuff, trachytic and tuffaceous sandstone about 1250 meters thick, and a lower one of andesite porphyry and andesitic tuff, with a thickness of about 300 meters. It is in the upper formation that all kinds of alteration with the development of the alunite beds of economic value are found. While no break has been actually observed between the andesite series and the overlying one, there are evidences indicating the existence of at least two erosion intervals in the lower part of the trachyte-tuff formation. This conclusion is evidenced by the presence of small clastic particles of volcanic origin in the two tuffaceous sandstone beds, No. 7 & No. 12 in the above table and which are to be interpretated to represent two inter-volcanic periods during which the volcanoes became temporarily dormant and erosion prevailed.

For the purpose of showing the nature and alteration of the volcanic rocks, some specimens are described in the next paragraphs. But the more or less alunitized rocks are treated in the chapter on "alunite deposits".

ALTERED AGGLOMERATE BRECCIA

(No. 5331, Location, north summit of Suantingshan 雙頂山, Point 23 in Pl. I)

Megascopic characters: A pyroclastic rock composed of a red matrix and white or red pebbles of volcanic origin.

Microscopic characters: This rock is distinctly clastic under the microscope. The white pebbles are slightly porphyritic rocks showing a faint trachytic texture, whose feldspar phenocrysts have been altered largely to kaolin, sericite, quartz and alunite, embedded in a groundmass consisting of fine secondary quartz grains and cryptocrystalline feldspar. The red pebbles are essentially similar to the white ones, but being dusted with abundant small hematite grains. The matrix is a mixed mass of minute secondary quartz, small cloudy feldspar and a small amount of alunite scales and prisms, here and there coated by a film of red iron oxide.

TRACHYTE PORPHYRY

(No. 5341. Loc., western end of the Taichiahang (戴家行) valley. P. 26 in Pl. I
Sp. Gr. = 2.475.)

Megascopic characters: A light grey rock with white lath-shaped feldspar phenocrysts, reaching a miximum length of 3 mm. They are surrounded by feldspar of smaller size.

Microscopic characters: It is an extensively decomposed and altered rock. The feldspar phenocrysts have mostly been changed into dusty kaolin, sericite, secondary quartz and a very small amount of kaolinite and acicular alunite crystals. Some crystals are comparatively fresh and the mean refractive index of which is about 1.54 or a little below 1.54, consequently they may belong either to orthoclases or to albite and oligoclase. Other minerals are rare. The groundmass consists chiefly of feldspar microlites and a small amount of fine magnetite grains.

ANDESITIC TUFF

(No. 5342. Loc., Panshihling (潘石嶺), P. 18 in Pl. I)

Megascopic characters: It is a dark purple, fine, loose and vesicular rock.

Microscopic characters: Under the microscope the rock is slightly clastic. A few dark-colored small pebbles, with more ferruginous material, are embedded in the matrix of lighter color. But the mineral compositions of the pebbles and matrix are essentially the same, as both are composed chiefly of small feldspar laths that embedded in a mixed dusty mass of red iron oxide, biotite, muscovite and others. Fine incipient quartz grains are also present, part of them, at least, serve as filling material in the minute vesicles. One large feldspar crystal has been found, being altered entirely to secondary quartz and others. Large magnetite grains are abundant, most of them are partly decomposed to hematite and limonite along their borders. The andesitic character of the rock is determined by megascopic character rather than microscopic.

ANDESITE PORPHYRY

(No. 5250. Loc., Taichiahang (戴家行), P. 27 in Pl. IX)

Megascopic characters: A purplish grey porphyritic rock. Phenocrysts and groundmass are nearly in equal proportion.

Microscopic characters: A groundmass chiefly composed of small plagioclase laths and also a small amount of minute magnetite grains are embedded with plagioclase phenocrysts of long prismatic form. As their refractive indices are slightly higher than 1.54 and their extinction angles +2° to -2° on (001), these crystals may have the composition of oligoclase to andesine. Both large crystals of hornblende and that of augite are common, but they are altered mainly to chlorite and various iron oxides. All forms of magnetite grains, large or small, fresh or altered, are present in the slide. Few epidote-like minerals have been found.

SILICIFIED FINE TUFF

(No. 5262. Loc., northern slope of Tungshan (東山), P. 2 in Pl. I)

Megascopic characters: A white, compact and vesicular rock scattered by white spots in certain portions.

Microscopic characters: This rock is almost entirely composed of fine incipient quartz grains, here and there dotted by irregular patches or nests of amorphous kaolin. Few small alunite scales have also been observed. In some portions, kaolinite and sericite aggregate constitute a rectangular outline; this may indicate the existence of a feldspar phenocryst in the original rock. Vesicles are abundant, most of them being left vacant. Several hematite grains, which have been partly altered to limonite, are found in the slide.

FERRUGINOUS SILICIFIED FINE TUFF

A poor siliceous iron ore. (No. 5978 Loc., summit of Chiaotzeting, P. 28 in Pl. I See Pl. VII, Fig. 3)

Megascopic characters: A reddish to black, hard but vesicular rock with intervening white patches.

Microscopic characters: The rock is composed chiefly of small grains of hematite, usually aggregated in irregular forms or nests and altered to limonite along their borders. Among the intervening spaces of the aggregates of hematite are irregular patches of fine incipient quartz grains. Vesicles are very abundant. Quartz may be partly coated by limonite and it seems that hematite was formed later than quartz.

C. ALLUVIUM

Its composition ranges from clay in the plain, loam near the foot-hills, to sandy loam, sand or sand loam and pebbles in alternation on the hill slopes. It occupies the flat piedmont plains and valley bottoms, and it is in these places that the small villages have been grown up.

D. STRUCTURE

The structure of this region is very simple; no faulting was observed while folding plays an important part in the tectonic history. The Jurassic quartzite formation exhibits a gentle anticline (Pl. II), whose axis lies in the valley south of Tienkuangshan in a ENE-WSW direction. The dip angle of its two limbs never exceeds 30 degrees. The volcanic series is generally tilted or warped toward W to S 70° W, with dip angles varying from 10°-60°, while 15°-30° being the most common recorded. Owing to their smaller size, both granitic and dioritic intrusions have exerted no or little influence on the geological structure. The dioritic intrusion east of Pochialing was only by chance to meet the axis of the Pre-Cretaceous anticline. Looking at it in a broad way, we may say that our area is located along the southern limb of a large syncline[1], whose east extension has been traced as far as

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[1] Mem. Geol. Surv. China Ser. A, No. 13, 1935, Fig. 1.

Nanking, while its northern limb extended as north as Chaohsien and Hohsien where Late Palaeozoic to Mesozoic formations occur. The simple tectonic history so far traced out in this area may be tabulated in ascending order as follows:

(1) Post-Jurassic and Pre-Cretaceous folding—the axis of folding is ENE-WSW.

(2) Post-Cretaceous (and Pre-Quaternary)[1] folding or warping with its axis of folding nearly parallel to a north-south direction.

IV. INTRUSIVE ROCKS

A. GENERAL CONSIDERATION

Altogether three different kinds of intrusive rocks have been found in this region, viz. microgranite, porphyritic syenite and diorite porphyry. Both field observation and theoretical deduction have shown that they were derived perhaps from the same magmatic source, and that their present differences in mineral composition, extures and characters are but a result produced by magmatic differentiation in the past. The microgranite crops out in the area between Tongchialing (董家嶺) and Kueishan and occupies a rather large area, being roughly in the form of a boss of limited extent but with a large part of it covered by alluvium. On the borders of this body the rock changes gradually into syenite which is slightly porphyritic in texture. The small outcrop at Tsatunwa (查屯凹) belongs also to such a type. The dioritic bodies are distinctly porphyritic and are situated further away from the central magmatic body just mentioned. Thus, a gradual variation of rock composition from acid to basic and of textures from equigranular to porphyritic is here clearly demonstrated.

The microgranite is fresh red in color and consists chiefly of pink orthoclase and soda-plagioclase crystals with an average length of one mm. Some quartz grains of smaller size are found. Hornblende crystals and biotite flakes are rare, though not absent. Pyrite grains are noted in some of the specimens. All these constitute a fine granular texture. Few large but weathered acid-plagioclase phenocrysts reaching a maximum length of 6 mm. are embedded in a groundmass exhibiting granitoid texture. Hence the name "microgranite" is proposed for this rock. It is only slightly altered.

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[1] At a place about 10 kilometers to the west of Hsiaofanshan, a slightly consolidated gravel bed, probably corresponds to the Tatung gravel of Quaternary age, has been found; without doubt it lies unconformably on the volcanic series. Hence this folding is possibly a Pre-Quaternary movement.

The porphyritic syenite constitutes the peripheries of the above mentioned intrusive body, and also crops out in the valley of Tsatunwa. It is also fresh red in color, but contains many large white and deeply altered acid-plagioclase phenocryts. Some orthoclase phenocrysts are also present. The groundmass of this rock differs from that of the microgranite by the absence of fine quartz grains and the more abundance of hornblende crystals.

Diorite porphyry usually occurs in small intrusive bodies of irregular shapes, but very narrow dikes or apophyses being also found. It crops out at Chiaotzeting, Shihtsaoling, Chunshanyuantze (鍾山園子), Panshihling, Chuntzeshan and in the valleys east of Yangshan (羊山; see Fig. 2) and Paochialing (卜家嶺) respectively. The rock is distinctly porphyritic with phenocrysts and the groundmass nearly in equal amount. Its color varies from dark brownish red, reddish purple to purplish or bluish grey according to a slight variation in mineral composition. The phenocrysts are composed chiefly of plagioclases of acid to intermediate types—ranging from oligoclase to andesine—and common augite or hornblende, with associated minerals such as magnetite, zircon and apatite. The groundmass consists of small feldspar, magnetite, augite, hornblende and others.

These three kinds of rocks are generally extensively altered in the alumstone-bearing regions, while those found in places far away from the alunite-rocks are usually more fresh and retain all of the original characters. The extremely altered ones are often very light in color, and also more soft, if not silicified.

Perhaps it is due to the smaller size of the intrusive bodies and the superimposed effect of the later alteration, that the influence of contact metamorphism is usually not easily recognizable in the country rocks. Whether or not the formation of Chuntzeshan quartzite may be attributed partly to the metamorphic effect of the intrusive rocks is not certain. Contact minerals have not yet been found in this region. On the other hand, similar to the volcanic rocks, these hypabyssal rocks have also been affected by similar processes of alteration which will be discussed in a later chapter.

B. PETROGRAPHIC DESCRIPTIONS

AUGITE DIORITE PORPHYRY

(No. 5328. Loc., Shihtsaoling, P. 24 in Pl. IX)

Megascopic characters: A purplish red to grey holocrystalline but porphyritic rock. The phenocrysts are less abundant than the groundmass and consist chiefly of slender lath-shaped feldspar and grains of augite, the former reaching a maximum length of 1.5 mm. The color becomes greyish and feldspar often changes to white when deeply weathered.

Microscopic characters: Among the phenocrysts the lath-shaped plagioclase in the most abundant constituent. Most of this mineral has been almost entirely altered to kaolin dusts and fine sericite scales, while others altered only along the peripheries with their central portions still fresh enough to be determined optically. From its optical characters,[1] this mineral is determined to be an oligoclase, having the composition of Ab_{75}, An_{35}. Both Carlsbad and Albite twining are present. Subordinate to the plagioclase is the short prismatic augite, some gives a positive optical sign and an extinction angle of 45° on (010). Most probably it is common augite. The mineral is somewhat altered along the cracks and borders, among the alteration products, iron oxide of various forms is the most abundant one, some greenish fibrous aggregates, probably uralite, are also present. Slightly altered magnetite grains and apatite crystals are frequently met with. Yellowish green hornblende, often extensively decomposed, and zircon are rather rare.

The groundmass is brownish red in color and consists mainly of feldspar, augite and magnetite of small size. Quartz grains has never been seen in this slide.

AUGITE DIORITE PORPHYRY

(No. 5352. Loc., Panshihling, P. 25 in Pl. I)

Megascopic characters: A porphyritic rock with greyish white to light grey plagioclase laths and short prismatic augite crystals scattered among a greyish and reddish purple groundmass. The plagioclase is 1-5 mm. long and 0.5 to 2 mm. broad and often shows polysynthetic twinning laminae. Phenocrysts and groundmass are nearly in equal proportion.

Microscopic characters: Under the microscope it is distinctly porphyritic. The phenocrysts and the groundmass may be described separately as follows.

Phenocrysts: Plagioclase is the most common constituent, usually in the form of large and long prisms. A great part of the crystals have been cracked and altered entirely or partly to sericite, amorphous kaolin, ... etc. Some of them are fresh enough to exhibit both Carlsbad and Albite twinning and give a positive optical character and an average refractive index of greater than 1.54, hence they may belong to the andesine class of plagioclase. Next to the plagioclase is the light yellow augite, occasionally showing simple twinning and often altered along the peripheries, partings and crevices. Most probably it is common augite as is

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[1] Optically negative, extinction angle 2° measured on the base and an index of refraction slightly greater than 1.540.

indicated by its extinction angle. Magnetite grains and apatite crystals are the common accessory minerals, while others are rare.

Groundmass: Similar to No. 5328, it is composed of minute feldspar laths, augite crystals and magnetite grains.

HORNBLENDE DIORITE PORPHYRY

(No. 5329. Loc., west of Panshihling, P. 19 in Pl. I)

Megascopic characters: A greyish purple, compact and porphyritic rock with light grey lath-shaped feldspar and greenish black long prismatic hornblende as its phenocrysts. The size of the feldspar is slightly smaller than that of No. 5352, and a majority of it belongs to the plagioclase as is indicated by the trace of Albite twinning on the surface.

Microscopic characters: Feldspar is the prevailing phenocryst, which is often extremely decomposed and altered to sericite and others. The facts that some fresh crystals have a mean index of refraction slightly greater than 1.54 and give positive or negative optical signs suggest that the feldspar belongs to the plagioclase class ranging from oligoclase to andesine. Slightly decomposed hornblende is very common. It is distinctly pleochroic, varying from greenish yellow (X), yellowish green (Y) to yellow (Z). Magnetite is the only important accessory mineral. The groundmass consists of small feldspar, hornblende and magnetite, all are deeply altered and decomposed.

HORNBLENDE DIORITE PORPHYRY

(No. 5330. Loc., west of Hochiatayuan (荷家大院), P. 17 in Pl. I)

Megascopic characters: It is essentially similar to No. 5329, only the feldspar phenocrysts are much larger, having a maximum length of 5.5 mm.

Microscopic characters: Feldspar is the most abundant mineral in the phenocrysts, being decomposed largely to a cloudy and turbid mass, occasionally exhibiting multiple twinning on the surface, and having an average index slightly greater than or equal to 1.54. It shows a negative optical character, so it is determined to be an oligoclase. The prevailing mafic mineral is hornblende, which is very similar to that in No. 5329, but has altered mostly to chlorite. Among the accessory minerals, apatite is the predominant element often occurring as inclusions in the forms of beautiful crosses and slender needles. Zoisite is also present, it gives an abnormal blue interference color, a biaxial positive optical character and a rather small optical angle. The brownish and greyish purple groundmass is composed largely of minute crystals of feldspar, hornblende and magnetite.

MICROGRANITE

(No. 5335. Loc., South-west of Tongchialing, P. 20 in Pl. I)

Megascopic characters: This rock is slightly porphyritic, with a few phenocrysts of white feldspar, about 4-6 mm. long and 2-3 mm. broad, embedded in a fresh red groundmass displaying a faint granitoid texture. The groundmass consists chiefly of fresh red orthoclase and perhaps also soda plagioclase crystals with a mean length of one mm. Some quartz grains of smaller size are present. Hornblende and biotite are rather rare, while grains of pyrite are also occassionally found.

Microscopic characters: The large phenocrysts are extremely altered into sericite and kaolinite and amorphous kaolin. Minerals that composed the groundmass seem to be less altered and exhibit a clear granitoid texture, which is more clear than when observed magascopically. Clear and fresh quartz grains in allotrimorphic forms occur as interstitial filling. The feldspar laths are usually extensively altered and none can be determined accurately by optical means. A great part of them, at least, are orthoclase as is indicated by a comparison of its refractive index with that of Canada balsam and quartz; while some crystals which exhibit trace of multiple twinning and give higher values of index of refraction, may belong to albite or oligoclase of the plagioclase class. Brownish yellow biotite which shows pleochroic halos and dark green hornblende are present, both being partly altered to chlorite. Magnetite grains in all stages of alteration and decomposition to hematite and limonite are found. A small amount of tourmaline showing a blue to green color is present, it shows a negative uniaxial optical character. Zircon and apatite may occassionally make their appearance.

PORPHYRITIC SYENITE

(No. 5337. Loc., Tsatunwa, P. 23 in Pl. I)

Megascopic characters: It is a fresh red porphyritic rock with greyish white or red feldspar and greenish hornblende as phenocrysts, which are less in amount than the groundmass. Feldspar crystals are generally 1-3 mm. in length and 0.5-1 mm. broad. Quartz grains are absent.

Microscopic characters: As compared with No. 5335, the following three things are worthy to mention:

(1) Quartz is absent.

(2) Feldspar has been extensively weathered and altered that makes accurate optical determination impossible. But as in the case of No. 5335, a large part of it may belong to orthoclase, and a small part of it may be acid-plagioclase.

(3) Hornblende and Magnetite are more abundant.

Thus, this rock may be properly named as porphyritic syenite or porphyritic hornblende syenite.

PORPHYRITIC SYENITE

(No. 5338. Loc., Kueishan, Tafanshan, P. 22 in Pl. I)

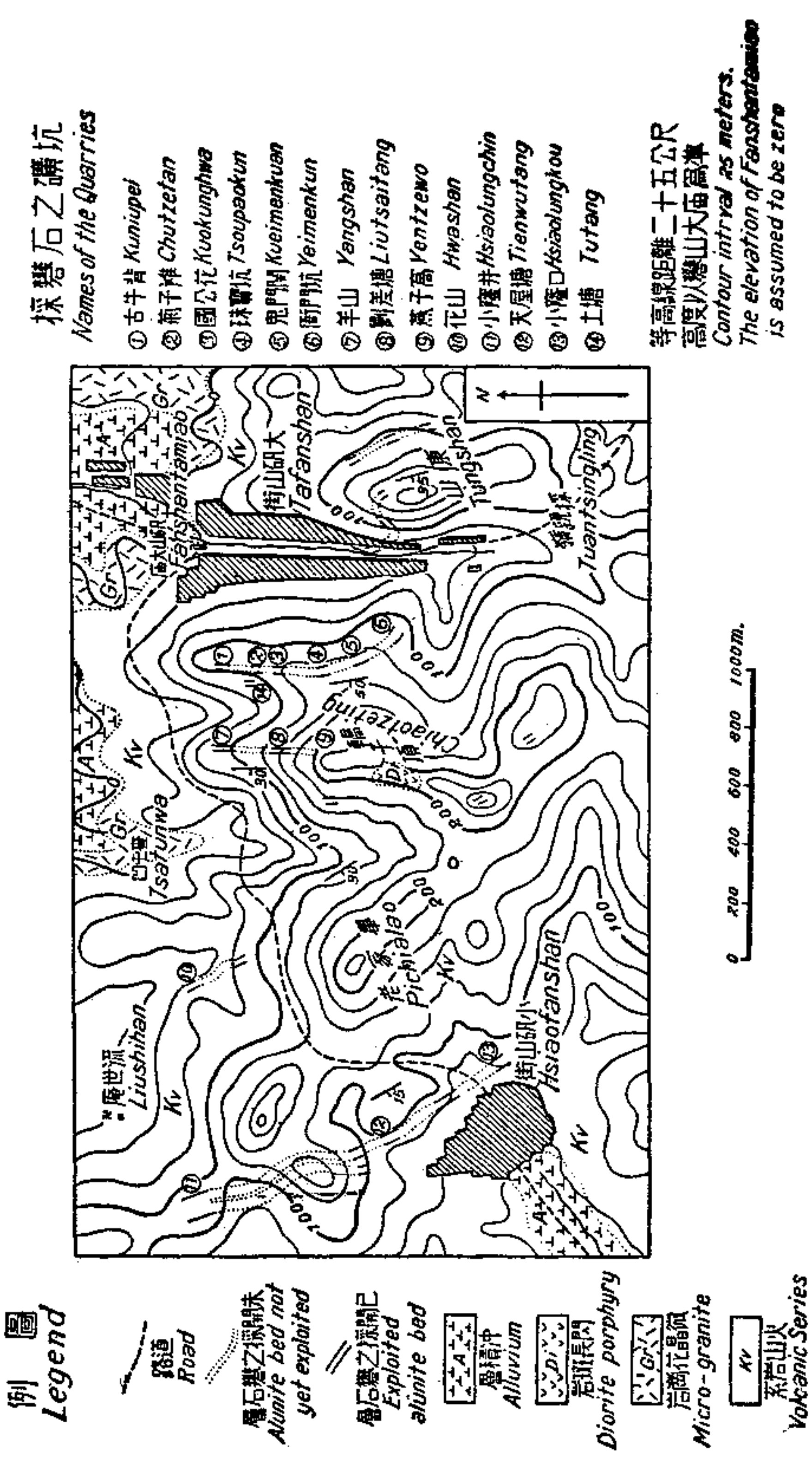
It is essentially similar to No. 5337, but its phenocrysts are much larger and more altered.

V. THE ALUNITE DEPOSIT

A. FIELD CHARACTERS

The most pure and high-grade alunite ore in this region as can be recognized from microscopic study as well as chemical analysis is collected from the Tsoupaokun (珠寶坑) quarry (point 4 in Plate II, see also Fig. 2) of Tafanshan. It is whitish gray in color, and fine and compact but massive in character. The fractured surface is subconchoidal and comparatively even. It looks very like a light grey siliceous limestone. The superior hardness—being greater than that of a knife edge—is due to its high silica content as a result of silicification process. Between the cross nicols it is seen to be composed of nearly 2/3 of small scale, and irregular fragments, of alunite, which are usually mingled with a considerable amount of minute quartz grains.

Those less pure and less alunitized ones are also whitish grey in color and often locally purplish tinted, but the subconchoidal fractures are seldom present. The appearance, texture and hardness vary greatly, consequently no generality can be obtained. Some of them may be comparatively soft and tuffaceous, or even very similar to a tuffaceous sandstone, while others may be very hard and quartzite-like. Some are very fine and compact, often with abundant small vesicle-like holes, while others may be distinctly porphyritic in texture but rarely vesicular, still a few is compact and fine-grained and characterized by the presence of numerous visible alunite crystals or scales. Such great variation is obviously due to the different degrees of alunitization and silicification as well as the differences of the original rocks.


圖例
Legend
道路 Road
未開採之礬石層 Alunite bed not yet exploited
已開採之礬石層 Exploited alunite bed
A 冲積層 Alluvium
Di 閃長斑岩 Diorite porphyry
Gr 細晶花崗岩 Micro-granite
Kv 火山岩系 Volcanic Series
採礬石之礦坑
Names of the Quarries
① 古牛背 Kuniupei
② 箭子樟 Chutzetan
③ 國公花 Kuokunghwa
④ 抹寶坑 Tsoupaokun
⑤ 鬼門關 Kueimenkuan
⑥ 斷門坑 Yeimenkun
⑦ 羊山 Yangshan
⑧ 劉蓋塘 Liutsaitang
⑨ 燕子窩 Yentzewo
⑩ 花山 Hwashan
⑪ 小龍井 Hsiaolungchin
⑫ 天屋塘 Tienwutang
⑬ 小龍口 Hsiaolungkou
⑭ 土塘 Tutang
等高線距離二十五公尺
高度以礬山大廟為準
Contour intrval as meters.
The elevation of Fanshentamiao is assumed to be zero
N
0 200 400 600 800 1000m.
礬山大廟 Fanshentamiao
大礬山 Tafanshan
東山 Tungshan
團青嶺 Tuantsingling
Chiaotzeling
Pichiailao
小礬山 Hsiaofanshan
Tsaitunwa
Liushihan
Kv
Gr
A
Di
100
200
300
150
95
75
50

Although the alunitized beds are widely distributed, only a few layers are rich enough to deserve the name of "alunite ore". Actually only six important alunite-rock layers have been discovered and quarried by the natives.[1] The first one located on the eastern slope of Tungshan (Pl. III, Fig. 3), is a richly alunitized tuff rock and is trending NNW-SSE with a dip angle of 40° to WSW, and having an average thickness of 4 meters, and a minimum length of 320 meters. It is underlain by a thick series of silicified and poorly alunitized tuff (No. 5262), and overlain by a thin layer of alunitized agglomerate (No. 5347) and then by greyish to purplish white fine tuff and tuffaceous sandstone, which are occasionally alunitized. The natives classify this layer as low-grade ore, but it is undoubtedly of medium- or high-grade according to the microscopic study of the specimens collected (No. 5628 and others). Even the overlying agglomerate is proved to be also composed of a considerable amount of alunite so that it may be served as a useful ore. The second one occurs on the top of the same hill and is embedded among a series of purplish and greyish white tuffaceous sandstone, it is poorer in alunite and is stratigraphically higher than the first one. It is only a few meters thick and has a longitudinal extension of about 150 meters. The third alunite-rock layer situated on the ridge and slope just west of the Tafanshan town is the most important and richest ore in this region. It is a combination of alunitized and silicified fine tuff, trachytic tuff and trachyte, which dip towards west to west-south-west with angle of 40° to 80°. The thickness is more than 50 meters for the whole sequence and 9 to 10.5 meters for the better ores, while the length is more than 700 meters. Both below and above this layer is the slightly alunitized variegated tuff or trachytic tuff. The famous quarries that are prosperous either in the past or at present, such as Kuniupei (古牛背), Chutzetan (菊子灘), Kuokunghua (國公花), Tsoupaokun (Pl. III, Fig. 3), Kueimenkuan (鬼門關), Yeimenkun (衙門坑), and Tutang (土塘), are all located along this horizon. The fourth one occurs on the north-south ridge north of Chiaotzeting and dips toward S 80° W with an angle of 30° or more and are embedded among a poorly alunitized tuff of light grey color. It is actually an united body of richly alunitized tuff and trachytic tuff (No. 5689 and others), with an average thickness of 8 to 10 meters and a longitudinal extension of 500 meters. The quarries under the name of Yangshan (羊山), Liutseitang (劉差塘) and Yantzewu (燕子窩) all exploit the alunite ore belonging to this layer. The fifth one crops out at Hwashan (花山; Pl. III, Fig. 5) and dips toward S 45°-60° W with a dip angle of 35°. It is a low-grade alunite ore, actually an alunitized trachyte porphyry (5333 and others) and has a mean thickness of 1.5 m and an approximate length of 300 meters. The

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[1] All the names of the quarries and places mentioned below are shown in Pl. II and Fig. 2.

alunite-rock in the abandoned quarry south of Chiaotzeting may be the south-eastern extension of this layer. The sixth alumstone layer appears in the vicinity of Hsiaofanshan town, being the longest and thickest one, though not the best, in the surveyed area. It is a combination of two parallel beds 600 to 1200 m. long, with dip angles of 15-35° toward S 60°-80°W, the characters of which are very similar to that of the third layer. The total thickness ranges from 30 to 60 meters, but that of the valuable ore is only 5 or 6 meters. The well known quarries of Hsiaofanshan such as Hsiaolungching (小礱井), Tienwutang (天屋塘; Pl. IV, Fig. 1) and Hsiaolungkou (小礱口) are all located along this bed; the ore produced from these three localities are either of medium-grade or of high-grade. Besides the workable alunite-rock beds just mentioned, there are still some small layers or veins that have been exploited by the local residents, but they are not important enough to be stated here. Furthermore, as a result of microscopic study of the specimens, the authors have found that those collected from a place about 300 m. north of Shiachiayuantze (No. 5350 and others) and 600 m. north of Shihtsaoling, (No. 5345) the rocks are alunitized and silicified porphyritic trachyte and tuff respectively and contains a percentage of alunite as high as 40%; consequently they may serve as ore for the manufacture of alum. Thus, with more detailed investigation

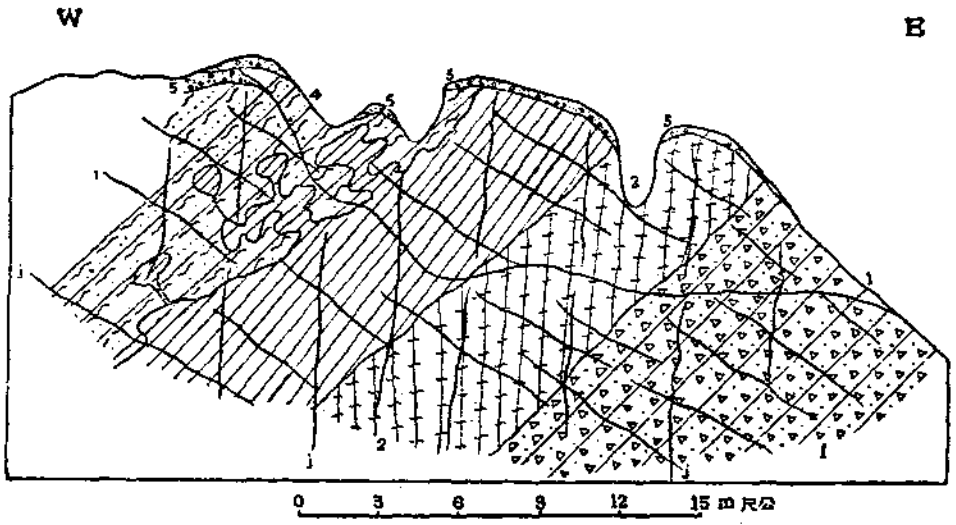

Fig. 3. A section showing the occurrence of alumstone in the Volcanic Series, Yangs
1. Light grey slightly alunitized tuff. 2 White alunitized tuff, the medium-rank alumst
3. Greyish white richly alunitized trachytic tuff, the high-rank alunite-rock. 4. Greyish white slightly alunitized trachytic tuff. 5. Surface covering—clay & rock fragments, j. Joint.

it is possible that more valuable alumstone layers or veins may be discovered in this region.

The alunite-rock layers or beds previously mentioned show usually irregular thicknesses; they may locally thin out, or to form pockets of great dimension.

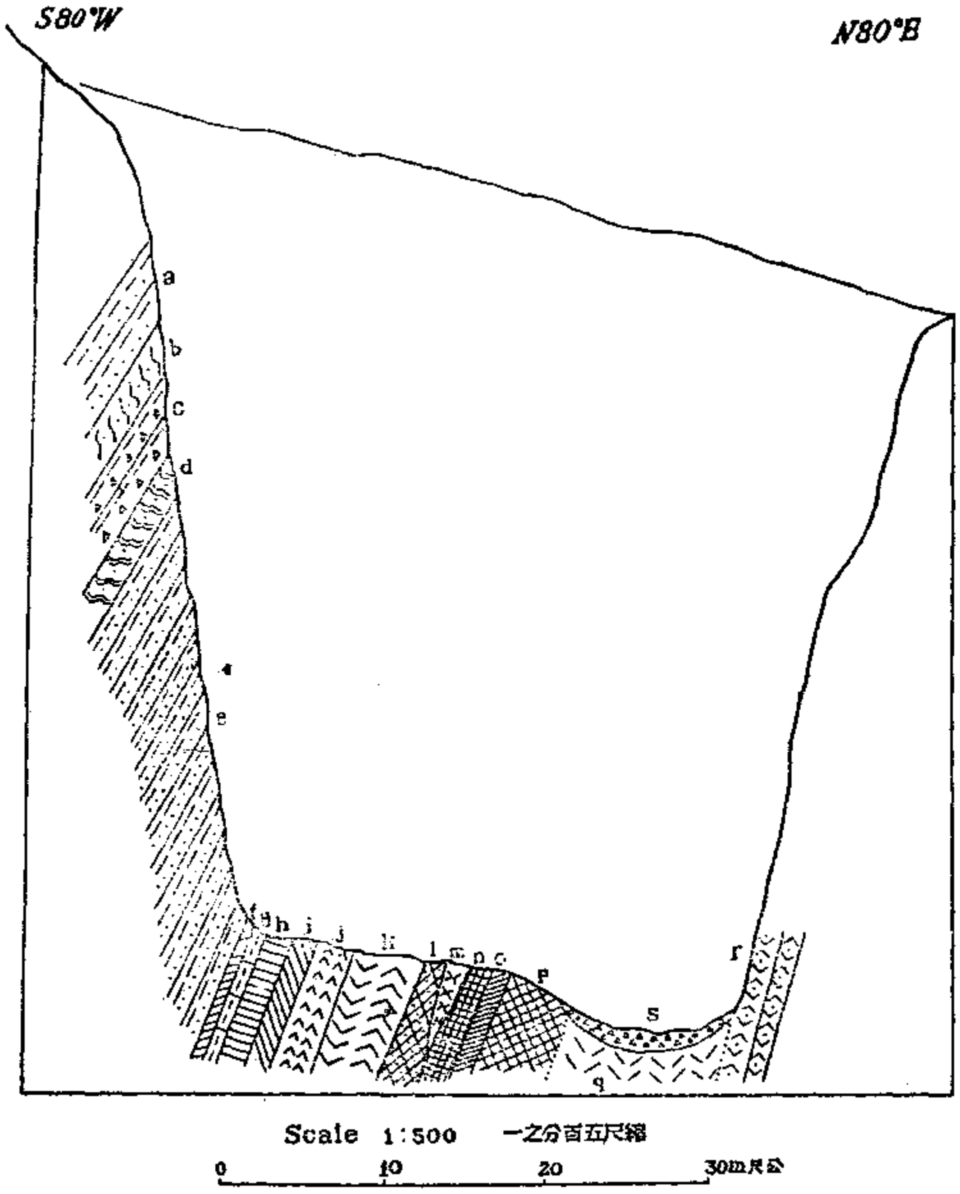

Fig. 4. A section across Tsoupaokun Quarry to show the succession of alunite deposits.

The following description of some sections across the alunite deposit serves to show the nature and form of replacement in the alunite formation.

A west-east section that taken from the northern part of Yanshan quarry is reproduced in Figure 3. In this section it evidently shows that although the alunite-rock is more or less in the form of a layer and is parallel to the bedding of the country rock, its boundary lines are by no means sharp and straight as a common sedimentary stratum should be, but generally showing undulating or even very irregular margins which is especially marked for the upper border. Such an irregular sheet is a typical form of replacement deposit, while the more sinuous shape of its upper brink may be due to the fact that the overlying country rock is more soluble and hence easier to be replaced than the underlying stratum. Both the country rock and the alunite-rock are seen to be cut across by three sets of joint, the first dips to west with an inclination of 80°, the second inclines toward NE with a dip angle of 40-50° and the third one dips to SE at an angle of 45°. Undoubtedly they are not tensional joints produced as a result of cooling, very likely they are the products of lateral compression or twisting acted on the rock when the latter has already well consolidated.

Another section cut across the famous Tsoupaokun quarry (Pl. III, Figs. 1 & 2) nearly in an east-west direction (Fig. 4) shows the succession of a thick series of alunite-rock. From the top to the bottom, the characters of the various layers are stated in the following:

No. of the layer (refer to Figure 4)	No. of the specimen	Rock Characters	Thickness	% of alunite determined micro-scopically
a		Grey silicified tuff, slightly alunitized	5 m+	less than 20%
b	No. 5949	Greyish white richly alunitized silicified tuff	2 m	40% ±
c		Pinkish grey tuff, slightly alunitized	3 m	less than 20%
d	No. 4960	White & pinkish white alunitized and silicified tuff	3 m	40% ±
e		Pinkish tinted white alunitized silicified tuff	18 m	28% ±
f	No. 4965	Greyish white slightly alunitized silicified with alunite scales	0.6 m	10% −

No. of the layer (refer to Figure 4)	No. of the specimen	Rock Characters	Thickness	% of alunite determined micro-scopically
g	No. 4964	White alunitized and silicified tuff with prominent acicular alunite crystals	0.9 m	30% +
h	No. 4972	Greyish white richly alunitized trachytic tuff showing fluidal structure	1.5 m	50% +
i	No. 4971	Greyish white alunitized and silicified trachyte	1.5 m	30% +
j	No. 4970	Purplish white alunitized trachyte porphyry, slightly silicified	2 m	40% ±
k	No. 4966 & 4968	Pinkish white alunitized and silicified tuff	4 m	40% ±
l	No. 4962	Pinkish white alunitized and silicified trachytic tuff	1.2-2 m	50% −
m	No. 4963	Greyish white alunitized and silicified trachytic tuff	0-1.15m	30% ±
n	No. 4969	Greyish white richly alunitized silicified fine tuff	1.3-2 m	50% ±
o	No. 4967	Greyish white richly alunitized silicified volc. breccia	1.2 m	40% ±
p	No. 4961	Pinkish tinted greyish white richly alunitized fine tuff, also silicified	5 m +	60% ±
q		Greyish white alunitized silicified tuff (almost entirely covered by rock fragments)	10 m −	40%[1] ?
r	No. 4973 & others	Purplish tinted white alunitized and silicified, volcanic breccia or agglomerate.	10 m	40% ±

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[1] Samples not collected, it is a medium-grade ore according to the oral information of the workmen in the quarry.

B. STUDY OF THE SPECIMENS

During the present investigation nearly 200 specimens of the alunitized rock have been collected by the writers. With a view to determine the origin and the nature of the deposit and to find out the mutual relationships between the different types so that a subdivision may be made according to their respective mineral composition, most of these samples are subjected to careful and systematic microscopic and chemical study, the resuls of which are to be described in the following sections.

(I) MICROSCOPIC STUDY

a. Advanced résumé

In the following paragraphs, the features of an individual alunite and the occurrence of alunite crystals in the rocks as well as their mode of replacement are stated first, then follows the classification of the alunitized rocks that based on the degree of alunitization and the nature of the original rocks.

In the thin slides of alunite-rocks, the alunite occurs mostly in micro-crystalline form, while only a few of it appears as phanero-crystalline constituent. Seven forms can be distinguished for their outer shapes, viz., long and narrow prisms (Plate VI, Figure 1; Pl. VIII, Fig. 4), fine needles (Plate VI, Fig. 2; Pl. VIII, Fig. 1) irregular fragments (Plate VII, Fig. 4), short prisms or prismatic plates (Plate VIII, Fig. 4), masses with fracture or cleavage lines (Plate VI, Figs. 3 & 4), large spinning-spindle-like body aggregated by small acicular crystals (Plate VI, Fig. 2) and fine scales (Plates VIII, Fig. 5; Pl. V, Fig. 3).

The optical character can be detected from all the forms except some extreme minute scales or irregular fragments. But those occur in the forms of prismatic plates, and spindle-shaped aggregates are especially favorable for such a study. Most of the prisms are elongated and developed along the vertical c axis. Under the plane-polarized light, the alunite is colorless and non-pleochroic, with rather high relief and fairly perfect cleavage cracks parallel to the direction of elongation, i. e., the c axis. Partings running in the direction parallel to c are occasionally seen. It shows an interference color ranging from upper first order to yellow color of the second between the cross nicols. Uniaxial positive figure can be obtained from those sections which give interference color of greyish yellow to bright yellow of first order. The refractive indices of the large crystals lie between 1.59 and 1.565. The biggest crystal so far observed in the collected samples is 3.5 mm. long and 1.5 mm. wide. Magascopically, the larger crystals exhibit a pinkish white color and a pearly luster and a hardness about 4, while the specific gravity of the purest specimen is 2.76.

Three types may be distinguished for the occurrence of the alunite crystals in the rocks. The first one is named as disseminated type. (Plate V, Fig. 3; Pl. VIII, Fig. 5). In such a case the alunite usually occurs as small irregular fragments and scales which mingle freely with other micro-crystalline or cryptocrystalline constituents. The alunite is rarely aggregated. The disseminated nature of the alunite crystals may be explained by the relative compactness and the comparative homogeneity of the original rock which enable the crystallization to begin at many points in the rock.

The second one may be called decussate type (Pl. V, Fig. 4; Pl. VIII, Figs. 1, 2 & 3). In rocks possessing this special feature, the alunite appears as needles or long laths of considerable size embedded at different direction in a fine groundmass of other minerals. Such a phenomenon may be probably due to the fact that the ascending solutions are rich in alunite substance so that larger but less crystals are formed. Furthermore, the rock might be less homogeneous than in the above case, so that crystallization began only at certain portions of the rock where the original mineral composition or other conditions were favorable for the formation of alunite.

Aggregated type comes as the third type. In this division, the alunite crystals are often aggregated in certain portions of a rock, and on the basis of their shapes of aggregation as well as their nature of formation this type may again be divided into several different kinds. Thus some alunite crystals are filling up the fissures in the original rock to form a narrow but rather regular vein (Plate VII, Figs. 1 & 2), while others may crystallize and cluster along the contact between pebbles and matrix or between the different fragmental elements of a clastic rock to form irregular elongated bands (Plate V, Fig. 4). In both cases they generaly grow in the direction of the fissures or contact lines, as there the space is less limited for their full development; but the small ones often grow at random. Sometimes, alunite may replace feldspar phenocrysts thus resulting in rectangular clustered forms (Pl. V, Fig. 2; Pl. VII, Fig. 2; Pl. VI, Figs. 3 & 4). In still other case the crystals may form irregular parches (Pl. V, Fig. 3) or bands as a result of indefinite replacement in certain portions of the matrix where it has been found to be more easily replaced as compard with other portions.

Regarding to their nature of replacement and filling, five forms may be recognized. The first one is "the phenocryst type" (Pl. V, Figs. 1 & 2; Pl. VI, Figs. 3 & 4; Pl. VII, Fig. 2; & others). Inasmuch as the phenocrysts in the acid volcanic rocks and intrusive rocks in this region are chiefly orthoclase, which contains a considerable amount of potassium and aluminum—both are essential to the process of alunitization—it is natural that they are more apt to be replaced by the alunite mineral than the groundmass. . Such is the case in porphyritic rocks as trachyte, trachytic tuff and diorite porphyry. The second form is the "general-replacement type" (Pl. V, Fig. 3; Pl. VIII, Figs. 1, 3 & 5), in which the original rock is mostly a fine tuff, which is thoroughly replaced by alunitizing solution due to their more homogeneous character, and the alunite thus produced often belongs either to the disseminated type or to the decussate type previously mentioned. "Matrix-replacement type" (Pl. V, Fig. 4) comes as the third form. Such is what one often observes in the clastic rocks, in which the matrix is usually less compact and more soluble than the fragments or pebbles and consequently more apt to be soaked by solution and more easily to be alunitized. The fourth and fifth forms are "fissure filling type" (Pl. VII, Figs. 1 & 2; and others) and "vesicle-filling type" (Pl. VIII, Fig. 2) respectively, which are self understood to need further explanations. Alunite that belongs to these two types are much less in amount, and the processes for their formation are far less important as compared with that of the replacement types. The "fissure-filling type" may represent a product of second alunitization as rocks that have alunitized by replacement are often seen to be cut through by veinlets of this type.

When considering the specimens as a whole, the alunitized rocks can be classified into four categories as according to their degree of alunitization and the nature of the original rocks. They will be discussed briefly one after another in the following paragraphs.

The first division is a slightly alunitized rock, in which the rock still retains most of its original characters and consequently can not be regarded as an alum-ore, though some of it may possess an alunite content as high as 33%. It is more dull in luster than the original rock and often silicified. As regards the original rocks, five different kinds have been observed. Diorite and trachyte are often extensively altered with their phenocrysts and groundmass partly replaced by alunite scales and plates. Fine tuff or trachytic tuff are seen to be composed chiefly of a fine cryptocrystalline feldspar-like substance also with a small amount of minute quartz grains and alunite scales, these three constituents are generally mingled together. Tuffaceous sandstone or coarse-grained tuff are distinctly clastic under the microscope, the fragments are altered chiefly into sericite and dusty kaolin; it is along the contact line of the fragments that small alunite crystals are frequently met with. In all these rocks hematite grains are always present, but they differ greatly in their relative amount.

The second type is a more alunitized rock as compared with the foregoing one and usually contains more than 40% of alunite so that it may serve as a fairly good ore for the manufacture of alum. The original rock is evidently a trachyte which often shows a porphyritic texture, but the typical trachytic texture has never been seen probably due to its advanced alteration. The phenocrysts are mainly feldspar, which is replaced chiefly by various forms of alunite, and to a less degree by minute grains of secondary quartz. Some extensively decomposed hornblende-like long prisms are present. Among the groundmass, alunite and secondary quartz predominate, and a considerable amount of strongly altered microcrystalline to cryptocrystalline feldspar is also found, but it is usually much less alunitized than the feldspar phenocrysts. Red and yellow iron oxides are locally met with and vesicles, that partly filled up by alunite or hematite, are of common occurrence. Fissure filling by veins of quartz, alunite and red hematite is commonly observed.

The third type is an alunitized fine tuff or trachytic tuff. They contain about 40%-50% of alunite and hence constituting a good ore. Fine tuff consists of extreme fine altered feldspar, secondary quartz and alunite, the latter may be very small, being either disseminated or aggregated. The trachytic tuff is essentially similar to the fine tuff, but may occasionally contain some small rock fragments and a few alunitized feldspar phenocrysts; two specimens even exhibit a clear fluidal structure. Both might be fissured and then filled up by alunite, quartz and others as in the above case.

Alunitized clastic rocks including tuff, breccia and agglomerate constitute the fourth group. Their alunite content is 40% or more and they are fairly good for alum-making. The clastic nature is very evident even seen by the naked eye. The clastic constituents vary from rounded pebbles 5 cm. or so in diameter and subangular fragments of smaller size to minute grains or even fine dusts. It is always true that the matrix contains more alunite laths and scales than the fragments—this fact has already been mentioned and explained in the foregoing paragraph. Between the clastic elements and along the contact between the matrix and fragments there are usually better developed laths and large aggregates of alunite crystals. Besides the alunite, secondary quartz grains and dusty feldspar-like small minerals are present in the matrix. Whenever they exhibit a porphyritic texture, the phenocrysts are often more alunitized than their respective groundmass. Hematite in the forms of particles and dusts occurs in variable quantity in the matrix as well as in the clastic constituents, but it often seems to be more abundant in the former. Veinlets of alunite and red iron oxide are often seen.

In studying the samples of these four types justed stated, two things are noticeable and interesting. Firstly, hematite grains or crystals are often seen to be altered into a milky white or greyish yellow amorphous substance which often constitutes a rhombohedral lattice and may or may not still include a few red hematite particles. It is believed that such material may be a certain kind of iron sulfate that formed by the attacking of a sulfate-bearing solution,—the same solution that accounted for the cause of alunitization in this region,—to the decomposed hematite crystals or grains, as milky white amorphous substance is actually seen to be associated with altered pyrite in thin slide of the specimen No. 5332 and decomposed hematite often displays such a rhombohedral frame-work. Secondly, the surface of the alunite is always water clear, while the neighboring fine feldspar-like mineral is constantly dusted with amorphous kaolin. This reveals the fact that the alunite is stable in nature and do not subject to change by weathering.

The fifth type is a richly alunitized rock—so far only one specimen is obtained—which is actually an extremely alunitized fine tuff, containing 60% or more of alunite. It is composed of homogeneously but exceedingly fine scale or irregular fragments of alunite with only a small amount of quartz, the former is often disseminated and seldom aggregated. Red iron oxides are rather rare.

All the important facts and results that obtained from the microscopic study of the samples have been fully mentioned in the above, while the deductions gained from such a study that may recast the possible way and condition of alunitization will be discussed in a later section. The detailed descriptions of the samples microscopically as well as megascopically run in the following paragraphs.

B. DETAILED DESCRIPTION

DIVISION I. SLIGHTLY ALUNITIZED ROCK

ALUNITIZED AND SILICIFIED TUFF

(No. 4960. Loc., Tsoupaokun d.[1] Tafanshan, point 4 in Pl. I. Sp. Gr. = 2.59)

Megascopic characters: A white and pinkish white tuffaceous but compact rock, partly tinted with red iron oxide and usually showing veiscular structure.

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[1] See Fig. 4.

Microscopic characters: Under the microscope, the clastic nature of the rock is rather clear and the slide is seen to be covered thickly by amorphous kaolin dusts and partly by hematite particles and grains. The fine clastic elements are closely joined together, with or without a small amount of minute matrix, and their individual boundaries are not very sharp as a result of strong alteration. Now the rock as a whole is composed mainly of very fine grains of cryptocrystalline nature, probably feldspar, which exhibit both low refringence and birefringence; but patches of fine quartz grains of secondary origin are also frequently met with. Alunite crystals of minute size are also found, being less common than quartz. It is concluded by microscopic study that the original rock is a vesicular tuffaceous rock of light color which was silicified and alunitized by certain silica- and sulfate-bearing solution—which may also carry a small amount of patassium and aluminium—and resulted in the present condition.

ALUNITIZED AND SILICIFIED TRACHYTE

(No. 4971. Loc., Tsoupaokun i, Tafanshan, p. 4 in Plate I. Sp. Gr. = 2.53)

Megascopic characters: A greyish white compact rock, with small vesicles on the surface. It is slightly porphyritic in texture, as shown by the presence of several white short prismatic crystals of altered feldspar.

Microscopic characters: The rock is only locally porphyritic due to the presence of lath-shaped feldspar crystals, which, owing to their extensive alteration into amorphous kaolin and alunite scales and prisms can only be recognized by their crystalline outlines under the plane polarized light. Besides these porphyritic portions, the rock is distinctly felsitic and consists chiefly of a mixed mass of cryptocrystalline to microcrystalline feldspar, minute secondary quartz grains and alunite, the last one nearly occupies 1/3 of the total area and usually occurs in the forms of small needles, plates and irregular fragments. The slide is generally covered by kaolin except where alunite is more predominant and nearly forms an aggregate of its own. Limonite that derived from other iron-bearing minerals is also present and serves as coating material in some portions.

ALTERED TRACHYTE

No. 5334. Loc., in the valley to the northeast of Hsiaofanshan,
point 14 in Plate I.)

Megascopic characters: A pinkish and greyish white vesicular rock, showing a distinct fliudal structure.

Microscopic characters: It is a felsitic rock composed almost entirely of fine quartz grains and altered feldspar, the surface of the latter is usually dusted with amorphous kaolin. If a considerable amount of the quartz is primary, it may be called a rhyolite rather than trachyte, but the discrimination between the secondary quartz and the primary one is very difficult in this slide. Hematite grains are locally present and sometimes may form a layer more or less parallel to the direction of flow. Vesicles are found and occasionally filled up by red iron oxide and kaolinite crystals. A very small amount of alunite scale is present.

ALTERED TRACHYTE (CONTAINING A DARK GREY XENOLITH)

No. 5332. Loc., in the valley to the northeast of Hsiaofanshan,

P. 14 in Pl. I.)

Megascopic characters: A compact rock consists of two different portions, the one (No. 5334) is pinkish and greyish white in color, vesicular in structure, and showing distinct fliudal bands, while the other is dark grey containing white rectangular phenocrysts, probably altered feldspar, and abundant disseminated small pyrite grains. Perhaps the latter is a xenolith that contained in the former.

Microscopic characters:

(a) Dark grey rock: It is a slightly porphyritic rock with few undeterminable altered feldspar crystals embedded in a groundmass composed of minute grains of quartz and feldspar; with the exception of quartz, all are somewhat clouded by a thin layer of kaolin dusts. Pyrite grains of various size are very abundant and scattered throughout the rock. Some of them have been partly decomposed into a milky white amorphous substance with several minute grains of pyrite still remaining unchanged. Such amorphous material more or less exhibit a faint lattice work, which would remind one the similar phenomena observed in slides of the specimens Nos. 4963, 4969, 4974, 5347, 5333 and 5339, but there the lattice texture is usually more clear and often with three sets of lines intersecting at 60° with each other and constructing a rhombohedron-like form, furthermore, hematite and limonite instead of pyrite are present. The vesicles are entirely or partly filled by bended vermicular kaolinite crystals.

As has already been stated in the foregoing description of No. 5339, such a milky white or greyish yellow amorphous substance is most probably a certain kind of iron sulfate, which is formed either from pyrite or from iron oxides during the processes of alunitization.

(b) Pinkish and greyish white rock:—It is similar to No. 5334. Greyish white bands are composed chiefly of fine grains of quartz and a small amount of feldspar, they may be the alteration products of the devitrified glass. The red bands consist of similar material but are usually covered by grains of red hematite, which is accompanied by a milky white substance, probably iron sulfate, whose rhombohedron-like lattice-work is discernible under the reflected light. Some vesicles are occasionally filled up by well formed kaolinite crystals and hematite grains. The slide is generally coated by a cloudy layer of amorphous kaolin.

ALUNITIZED DIORITE PORPHYRY

(No. 4974. Loc., in the valley to the north of Chiaotzeting, P. 8 in Pl. I. See Pl. VI, Figs. 3 & 4.)

Megascopic characters: It is a purplish grey rock with white feldspar phenocrysts embedded in a purplish groundmass. The surface is here and there scattered by many brownish yellow spots.

Microscopic characters: It is a porphyritic rock whose texture can be clearly detected by plane-polarized light. The groundmass is composed chiefly of fine grains of minerals of low refringence and birefringence, probably feldspar, being somewhat clouded by net-work of amorphous kaolin and other altered minerals. But alunite also constitutes a considerable part of it. The phenocrysts are predominantly feldspar crystals, which have been changed mainly to kaolin and alunite, and to a less degree to quartz and sericite, hence the characteristics of a feldspar mineral are almost entirely lost, only its rectangular crystalline outline is still remained. Brownish yellow opaque grains of various size are very abundant, the larger ones are just clear enough to be detected by reflected light, being composed of a brownish yellow frame work with intervening yellowish white substance; it is likely that they may be limonite-like materials derived from hematite or magnetite.

STRONGLY ALTERED TRACHYTE PORPHYRY

(No. 5333. Loc., Hwashan, N. E. of Hsiaofanshan, P. 13 in Pl. I)

Megascopic characters: A reddish white rock with white rectangular phenocrysts.

Microscopic characters: It is a porphyritic rock whose groundmass is composed of secondary quartz, kaolinite, kaolin dusts, hematite grains and other undeterminable substance, the former three are evidently derived from some pre-existing material. The phenocrysts are rather abundant and consist largely of feldspar crystals and to a less extent of hornblende-like mineral. But they have been almost entirely altered to other minerals of smaller size and only their crystalline outline can still be clearly seen. The alteration products of feldspar are chiefly vermicular kaolinite and sericite, while quartz, high-birefringent-chlorite and alunite also constitute a considerable part of them. Hornblende-like mineral is usually changed to chlorite and others. Few quartz grains of rather large size are present, they may be of primary origin. Several extremely decomposed ferruginous minerals are found, being coated by milky white iron sulfate. Whenever fissures are present in the groundmass, they are always seen to be filled up by small kaolinite crystals.

SLIGHTLY ALUNITIZED TUFFACEOUS SANDSTONE

(No. 5347. Loc., northwest of Tsoupaokun, Tafanshan, P. 7 in Pl. I. Sp. Gr. = 2.37)

Megascopic characters: A purple- and white-banded tuffaceous sandstone, which is not very compact and is slightly alunitized.

Microscopic characters: Originally it must be a medium-grained rock composed chiefly of small fragments of volcanic origin, but later on, the clastic elements were usually altered to fine sericite scales, small crystals of kaolinite, and few other cryptocrystalline or amorphous substances. The initial boundaries between the various fragments can still be discerned by the reflected light, and it is along the contact line that alunite crystals and hematite grains are often met with. White iron sulfate is also present in certain portions of the slide.

DIVISION 2. ALUNITIZED TRACHYTE

ALUNITIZED TRACHYTE PORPHYRY, SLIGHTLY SILICIFIED

(No. 4970. Loc., Tsoupaokun j, Tafanshan, P. 4 in Pl. I Sp. Gr. = 2.59)

Megascopic characters: A purplish to pinkish white, vesicular but compact rock. Many white phenocrysts are present.

Microscopic characters: Porphyritic texture is very distinct.

a) Groundmass—It consists of a predominant quantity of fine quartz grains and a less amount of minute prismatic alunite crystals. They are usually dotted with numerous hematite grains and scattered by amorphous limonite and kaolin on the surface, probably the latter two are alteration products. Vesicles are not uncommon, short prismatic alunite crystals are often seen to be grown on their edges and projected toward the open space in the center.

b) Phenocrysts—The phenocrysts are chiefly feldspar. Though still possessing the crystalline outline of a feldspar crystal, yet it has been entirely changed to other minerals of much smaller size. The alteration products are composed mainly of alunite and to a less degree of quartz. The surface is rather clear and is free from the coating of cloudy dusts. Such a contradictory phenomenon as compared with the groundmass manifests two facts, (1) both alunitization and silicification are later than the formation of hematite hence the latter may be a primary mineral of the original unaltered rock, and (2) originally, the groundmass contains a rich amount of ferruginous material, while the phenocrysts are almost entirely free from iron content.

ALUNITIZED AND SILICIFIED TRACHYTE PORPHYRY

(No. 5350. Loc., north of Shiachiayuantze, P. 12 in Pl. I. Sp. Gr. =2.605)

Megascopic characters: It is a purplish white compact rock with white lath-shaped phenocrysts, probably feldspar. Vesicles are locally present.

Microscopic characters: The volcanic origin of the rocks is shown by the presence of numerous vesicles and the extreme fineness of the groundmass. Its porphyritic nature is clearly indicated by the crystalline outline of feldspar phenocrysts under the reflected light. But when the slide is examined between cross nicols, feldspar is seen to be largely altered to acicular alunite crystal and quartz, that embedded in a groundmass composed of similar mineral constituents but of smaller size, hence the contact between the phenocrysts and the groundmass can hardly be seen. Few extremely decomposed hornblende-like long prismatic minerals are also found, they are altered mainly to chlorite and are replaced partly by small quartz grains. Hematite grains in all stages of alteration are frequently met with. Vesicles are not rare, being chiefly filled up by small quartz grains, and to a much less degree by kaolinite crystals. The slide is usually covered by amorphous kaolin and occasionally cut through by veinlets of fine quartz grains. By approximate estimate, alunite occupies nearly one half of the whole area of the slide, so this specimen may serve as a workable ore of alum.

ALUNITIZED TRACHYTE PORPHYRY

(No. 5630. Loc., Tutang, Tafanshan, P. 6 in Pl. I.
Sp. Gr. = 2.75.)

Megascopic characters: It is a light grey, compact and fine grained rock, being partly red tinted.

Microscopic characters: It belongs to phenocryst-replacement as well as fissure-filling type of the alunite rock; the groundmass is replaced by alunite to a less degree than phenocrysts. The rock is slightly porphyritic under the microscope, only with few large phenocrysts embedded in the minute grains of the groundmass. Among the phenocrysts, lath-shaped feldspar predominates, which has been replaced mainly by alunite crystals and occasionally by quartz grains; 2 or 3 individuals of thoroughly decomposed hornblende-like mineral and some quartz grains are also found. The groundmass is composed of minute grains of quartz-like mineral and alunite, which are evidently of secondary origin. It is locally covered by aggregates of hematite grains or limonite and cut through by veinlets composed of alunite crystals and hematite grains, the latter is probably formed after the former. Thus, two stages of alunitization can be distinguished in this slide, the first one accounts for the general alunitization of the whole rock while the other is only a subordinate process much later in time than the former—it came into existence after the alunitized rock had been fractured by many crevics. Alunite occupies nearly half of the total area of the slide.

DIVISION 3. ALUNITIZED FINE TUFF & TRACHYTIC TUFF

ALUNITIZED & SILICIFIED FINE TUFF

(No. 4964. Loc., Tsoupaokung, Tafanshan, P. 4 in Pl. I.
Sp.Gr. = 2.51. See Pl. VI, Fig. 2,)

scopic characters: A white compact rock which contains many pinkish -shaped and pearly minerals (alunite). Vesicles are locally present.

Microscopic characters: The rock is almost entirely composed of minute grains of quartz and feldspar-like minerals, with many large acicular alunite crystals scattered among them. The slide is locally coated by a thin film of kaolin.

Several patches of greyish white amorphous substance, probably iron sulfate, have been seen under the reflected light, they are occasionally accompanied by small hematite grains.

Description of Alunite:

a) Natural size: from a tenth of a mm. to 2 or 3 mm. in length.
b) Shape: acicular or needle-shaped, occasionally scaly
c) Color: pinkish white to greyish white
d) Luster: pearly
e) Hardness: < knife edge, 4—

f) Index of refraction: 1.59—1.565
g) Polarized light: Colorless; relief moderate; no pleochroism, cleavage ‖ to the elongation of the crystal.
h) Crossed nicols: paralleled extinction; negative elongation; moderate birefringence, interference color usually yellow of the second order.
i) Convergent light: Uniaxial, + character.

ALUNITIZED AND SILICIFIED FINE TUFF

(No. 5345. Loc., north of Shihtsaoling, P. 11 in Pl. I.
Sp. Gr. = 2.49. See Pl. VIII, Fig. 1)

Megascopic characters: It is a yellowish white quartzite-like fine rock. Vesicles, which are usually partly filled by hematite grains, are very abundant.

Microscopic characters: The volcanic origin of the rock is shown by the abundance of small vesicles, which are entirely or partly filled by iron oxide now usually in the form of limonite. Numerous acicular alunite are scattered among a mixture of microcrystalline quartz and also scaly alunite. All are of secondary origin. Alunite crystals occupy nearly half of the total area of the slide, and consequently the rock may serve as an ore for alum. Limonite coating in the form of dusts are only locally met with.

ALUNITIZED FINE TUFF

(No. 5629. Loc., Yangshan, P. 9 in Pl. I. Sp. Gr. = 2.62.)

Megascopic characters: It is a greyish white hard and dense rock. Patches of red iron oxide are present in certain parts.

Microscopic characters: It is similar to No. 5628 and belongs to the disseminated type of alunite-rock. Alunite, usually in the form of minute short prism, mingles thoroughly with small quartz-like grains. The slide is locally covered by red hematite grains. Alunite crystals occupy half of the total area of the slide, hence this rock is an ore of high-grade.

ALUNITIZED TRACHYTIC TUFF

(No. 4972. Loc., Tsoupaokun h, Tafanshan, P. 4 in Pl. I. Sp. Gr. = 2.75)

Megascopic characters: A greyish white compact rock.

Microscopic characters: It is a felsitic but somewhat clastic rock, being composed partly of minute grains of quartz and some feldspar-like mineral, which is generally coated by yellowish and whitish amorphous dusty particles. The whitish apriicles may be kaolin, while the yellowish ones are somewhat like limonite—posssibly derived from hematite or other ferruginous minerals. But there are certain clear portions in the slide where fine alunite scales and crystals, in the forms of aggregated irregular patches and fissure-filling veins, are present; this mineral occupies more than half of the whole area. The supposed iron sulfate is seen in certain portions. Few magnetite grains are present, they are only slightly altered on the margins. The rock exhibits an original flow structure under the plane polarized light.

ALUNITIZED TRACHYTIC TUFF

(No. 5632. Loc., Tienwutang, Hsiaofanshan, P. 5, Pl. I. Sp. Gr. = 2.59)

Megascopic characters: It is a purplish white fine rock, being slightly vesicular and comparatively soft. Purplish red bands or patches are present.

Microscopic characters: It belongs to the disseminnated-type as well as general-replacement type of the alunite-rock and is slightly porphyritic. Phenocrysts are very scant, and consist chiefly of long prismatic and cloudy minerals, probably extremely decomposed and altered feldspar. Sometimes they are dotted by small hematite grains. The groundmass is composed of a mixture of small alunite crystals and quartz grains, the former is more abundant and occasionally aggregated. It is frequently cut through by small veinlets of alunite needles or prisms and locally covered by hematite grains. Thus, here again two periods of alunitization can be discriminated as in the case of No. 5630. Quartz grains and kaolinite scales of considerable size are seen to be present in some vague space. The volcanic origin of the rock is very evident, as is shown by the fluidal structure still preserved and the abundance of vesicles. It is also slightly clastic in structure in certain parts.

DIVISION 4. ALUNITIZED TUFF, BRECCIA AND AGGLOMERATE

ALUNITIZED AND SILICIFIED TUFF

(No. 4959. Loc., Tsoupaokun b, Tafanshan, P. 4 in Pl. I.
Sp. Gr. 2.59. See Pl. VI, Fig. 1; Pl. VIII, Fig. 5)

Megascopic characters: A greyish white, compact but tuffaceous rock, which exhibits vesicular structure in certain portions.

Microscopic characters: The fragmental structure of the rock is rather clearly shown the under microscope. The matrix is much more in amount than the fragments. Originally, the clastic particles are composed chiefly of feldspar, but all have been changed to fine scales, needles or laths of alunite and fine granular quartz, the latter only occupies a very small part of the alteration products. The fine grains between the fragments are seen to be composed mainly of minute scales of alunite and fine quartz grains, all being mingled together freely. But along several fracture lines, alunite scales are particularly abundant, and they give a general direction of optical orientation and also a similar order of interference color. Alunite occupies about half of the whole area of the side, and its maximum length is 0.35 mm. Some grains of a certain ferruginous mineral, now largely in the form of iron sulfate, so supposed, with disseminating limonite powders on the surface, are present.

ALUNITIZED TUFF

(No. 5631. Loc., Hsiaolungkou, Hsiaofanshan, P. 16 in Pl. I Sp. Gr. = 2.61)

Megascopic characters: It is a greyish white compact clastic rock.

Microscopic characters: The rock is of clastic origin and consists of small rock grains and very fine cement. It is covered by hematite grains in certain part. The cement is usually replaced by alunite crystals and with more clear surface, while the rock grains are composed of minute cryptocrystalline substance and only occasionally replaced by alunite, and their surface is frequently coated by cloudy dusts of amorphous kaolin. Vesicles are infrequently met with; wherever present, they are almost always filled up by alunite and only incidently by quartz. Alunite occupies nearly half of the total area of the slide.

ALUNITIZED VOLCANIC BRECCIA

(No. 4967, Loc., Tsoupaokou, Tafanshan, P, 4 in Pl. I.
Sp. Gr. = 2.61. See Pl. V Fig. 4 and Pl. VIII, Fig. 4)

Megascopic characters: A greyish white, compact but clastic rock with several greenish grey small pebbles.

Microscopic characters: It is distinctly clastic in structure and consists mainly of alunite crystals of secondary origin. Decomposed magnetite and hematite grains —the latter being altered partly to amorphous iron sulfate—are common in certain portions. The longest crystal of alunite so far measured is 1.6 mm. long.

ALUNITIZED & SILICIFIED AGGLOMERATE OR BRECCIA

(No. 4973. Loc., Tsoupaokun r, Tafanshan, P. 4 in Pl. I. Sp. Gr. = 2.53.
See Pl. VII, Figs. 1 & 2)

Megascopic characters: A clastic rock composed of red matrix and white pebbles.

Microscopic characters: Pebbles are very cloudy due to the covering of dusty kaolin developed from the feldspar, and consist principally of fine grains of quartz and feldspar with a small amount of alunite crystals scattered among them. They are slightly porphyritic in nature, being shown by the presence of many altered rectangular feldspar phenocrysts, which have been changed mainly to fine alunite, quartz grains, dusty kaolin and others. Red hematite grains, though not absent, are only rarely met with. So-called red matrix is composed of a predominant quantity of alunite crystals and a subordinate amount of quartz and other fine mineral grains, the surface of the former two components is almost entirely free from any trace of amorphous kaolin but being densely covered by numerous red hematite granules. Some narrow veinlets consist mainly of small alunite crystals, lying perpendicular to the vein walls, are seen to cut through either pebbles or the matrix that has been previously alunitized. The alunite that contained in these small veinlets may represent another stage of alunitization, which is unimportant and later in time as compared with the first one. Sometimes, hematite grains are also found in the veinlets; whenever present, they are usually not abundant and only adhere to the sides of the veins or tend to fill the crevices between the alunite crystals. Most probably, they were formed later than the alunite in the veinlets. By approximate estimation, alunite occupies one third to one half of the whole area of the slide.

ALUNITIZED AGGLOMERATE

(No. 5346. Loc., eastern slope of Tungshan, P. 1 in Pl. I. Sp. Gr. =2.615.
See Pl. VII, Fig. 4; Pl. V, Figs. 2 & 1.)

Megascopic characters: It is a pink and greyish white rock with red and yellow trachyte pebbles.

Microscopic characters: The rock fragments are slightly porphyritic in nature whose feldspar phenocrysts have been altered chiefly to alunite which occurs in the forms of scales and irregular fragments, and to a less extent to sericite scales, quartz grains and kaolinite crystals. The groundmass consists of similar constituents of smaller size, but of different proportion, and is uniformly dotted by abundant hematite grains, which altered partly to limonite and amorphous iron sulfate, and dusted with cloudy kaolin. Alunite seems to be more abundant in the matrix. Veinlets composed of small hematite grains—occasionally containing some alunite—are rather common and cut through both pebbles and the matrix that have already been entirely or partly replaced by alunite; in some cases an alunite crystal is actually seen to be cut across by such veinlets. Nearly half of the area of the slide is occupied by the alunite mineral.

DIVISION 5. RICHLY ALUNITIZED ROCK

RICHLY ALUNITIZED & SLIGHTLY SILICIFIED FELSITE OF FINE TUFF

(No. 4961 Loc., Tsoupaokun p, Tafanshan, P. 4 in Pl. I. Sp. Gr. = 2.76. See Pl. V, Fig. 3)

Megascopic characters: A pinkish white, hard and compact rock showing sub-conchoidal fracture.

Microscopic characters: A felsitic rock almost entirely composed of alunite crystals and quartz, the former being more abundant. A small amount of minute feldspar-like mineral whose surface is usually coated by cloudy kaolin dusts is also present. The alunite forming minute grain and short prismatic crystal, is disseminated throughout the rock mass, but locally it may aggregate along certain directions and form irregular bands and patches. This rock serves as an excellent ore for the manufacturing of alum, as alunite occupies two thirds or more of the total area of the slide.

(2) CHEMICAL COMPOSITION

(By S. Y. Hsiung)

Twenty-four samples of alunitized rock[1] and alumstone were chosen for analysis. The powdered alunite (100 mesh) was fused with sodium carbonate, and the silica, ferric oxide, alumina, calcium oxide and sulfur trioxide were determined by procedures recommended by Hillebrand and Lundell[2] (1), (2), (3), (4), (5). As the amount of iron in the sample is small in comparison with that of alumina, it was precipitated with cupferron after the purosulfate fusion of the "combined oxides", leaving alumina determined by difference. Potash and soda were determined together by J. Lawrence Smith's method as chlorides from another sample and then separated by perchloric acid (6). Combined water (H_2O+) was obtained by subtraction of the hygroscopic water (H_2O^-) (7) from the total, which was conveniently determined as follows:

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[1] Here the name "alunitized rock" is arbitrarily restricted to the rock, that contains a certain amount of alunite but has not yet been used by the native people for alum-manufacturing.

[2] Literature Cited.

Numbers refer to pages on "Applied analysis, Hillebrand Lundell".

(1) 719, 707-710.
(2) 723-726.
(3) 730, 734-737, 704-705, 109-111.
(4) 744, 497-500.
(5) 575-578, 880, 811.
(6) 788-792, 534.

About 0.5g. of alunite was mixed well in a weighed porcelain crucible with 3g. of pure sodium tungstate (8). Ignition was started gently, and then the temperature was increased gradually until the mixture formed a clear fusion (about 600°C). After cooling in a desiccator, the crucible was weighed, and the loss in weight represented the total water. This procedure was found to be just as satisfactory as that given in Hillebrand and Lundell (9).

The percentage of pure alunite with formula $K_2O.3Al_2O_3.4SO_3.6H_2O$ was calculated on the basis of potash. The results of analyses are listed in Table 1.

The Luchiang alumstone as shown by analysis is always high in silica, 45% being the average, this is due to the fact that silicification is the most important process of alteration in Fanshan area. Calcium oxide is seldom more than 0.2%. Magnesia, phosphorous pentaoxide, etc. are considered to be negligible and are not determined. There is always excess of alumina, sulfur trioxide, and water over potash to form pure alunite, except those in "Tsoupaokun f" and "East of Yangshan", in which the amount of potash is the least. Some samples are quite rich in sodium content. Thus, the alunite that occurs in the rock is by no means a pure potassic mineral, and consequantly the % of alunite actually present in the samples must be greater than that calculated on the basis of a pure alunite mineral.

(3) SPECIFIC GRAVITY

The specific gravity of the thirty-one pieces of rock specimens was determined by the writers, among these samples, 24 pieces are alunitized rocks—often also silicified—and the other seven are altered extrusive rocks. While the value of the specific gravity of alunite mineral given in the various text books varies from 2.58-2.68, the figure for the alunitized rocks here determined ranges from 2.485-2.77. This variation is obviously due to their difference in the alunite content and their heterogeneous nature of the original rock from which the alunite has been formed by alteration.

The specific gravity thus determined is listed in Table 2. The approximate amount of alunite present in the different rocks as estimated microscopically and their respective % of alunite determined by chemical analysis are also listed in their proper positions. The overestimate of the amount of alunite in the rocks by the microscopic study as compared with the values obtained by chemical analysis may be attributed to the fact that the Na_2O molecule has not been considered in the

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(7) 687-689.

(8) Foot-note, 697.

(9) 697.

Table 1. Analyses of Alumstones and Alunilized Rocks

Rock number	Location of Sample*	SiO_2	Fe_2O_3	Al_2O_3	CaO	SO_3	K_2O	Na_2O	H_2O^-	H_2O^+	Total	$K_2O.3Al_2O_3.4SO_3.6H_2O$
5949	Tsoupaokun b	49.42	1.68	19.14	.93	18.23	2.26	3.22	.15	4.54	99.57	19.87
4960	" d	47.06	2.19	20.10	.39	18.29	4.00	1.13	.16	7.06	100.38	35.18
4965	" f[1]	89.74	4.26	.46	Trace†	2.45	.55	.22	.11	.43	98.22	——
4964	" g[1]	71.37	3.01	8.83	"	10.83	2.41	.42	.07	3.43	100.37	21.19
4972	" h	36.65	1.98	23.11	"	23.65	5.40	.75	.14	7.84	99.52	47.49
4971	" i	58.49	2.08	15.64	"	15.33	3.74	.44	.12	5.12	100.96	32.89
4970	" j[1]	55.67	6.37	15.00	"	14.56	3.01	.61	.14	5.12	100.48	26.47
4968	" k[1] (upper part)	51.96	5.77	16.03	.29	16.02	2.97	.75	.11	5.76	99.66	26.12
4966	" k[1] (lower part)	48.38	8.01	16.69	.47	16.97	3.41	.55	.11	5.89	100.48	29.99
4962	" l	46.68	4.04	18.46	Trace†	18,72	3.89	.34	.08	6.38	98.59	34.21
4963	" m[1]	62.81	4.22	13.10	"	12.88	2.75	.57	,07	3.99	100.39	24.18
4969	" n	42.64	2.46	21.59	"	20.90	4.91	.56	.09	7.21	100.36	43.18
4967	" o[1]	55.26	4.25	16.05	"	15.33	3.22	.60	.10	5.13	99.94	28.32
4961	" p	28.82	2.42	26.18	"	25.60	6.05	.38	.08	8.74	98.28	53.29
4973	" r	47.04	3.36	19.26	"	18.31	3.42	1.41	.08	6.70	98.58	30.08
5629	Yangshan (2)	39.21	2.96	23.32	"	21.11	4.18	1.80	.08	7.68	100.34	36.76
5621	Yangshan (1)	56.52	3.68	14.92	"	15.34	3.02	.86	.08	5.08	99.50	26.56
5339	Kuniupei	51.58	5.01	17.09	"	16.09	3.48	.17	.11	5.84	99.37	30.60
5346	Tungshan (1)	48.68	2.83	19.55	"	16.41	3.29	1.20	.10	6.75	98.81	28.93
5628	" (2)	48.89	2.83	19.15	"	18.09	3.82	.74	.10	6.10	99.72	33.59
5360	Tutang	47.11	3.97	18.96	"	18.93	3.93	.90	.10	6.15	100.05	34.56
4974	East of Yangshan[2]	56.91	3.60	26.51	"	1.41	.88	.50	1.05	8.46	99.32	——
5634	Tienwutang	47.56	3.48	21.78	"	14.90	3.31	.15	.11	7.36	98.65	29.11
5631	Hsiaolungkou	46.10	4.75	21.14	"	16.63	3.89	.09	.13	7.04	99.75	34.03

† The amount of CaO if present is less than 0.2%

[1] Samples not yet used by the native people for alum-manufacturing.

[2] An altered diorite porphyry; point 8 in Plate I.

* All these names mentioned under this column are shown in Fig. 2; the names of the various horizons at Tsoupaokun quarry are shown in Fig. 4 and have been enumerated on pp. 21-22. The subdivision of "Yangshan" is shown in Fig. 3.

Table 2. Specific Gravity of the Alunite-rock

Variety	Specific Gravity	Accession No. of the Rock Specimen	Relative Vol. of alunite in slide estimated micro-scopically	% of Alunite deter-mined by Analysis[1]	Remark
Tuffaceous Sandstone	2.34	No. 5343	trace		Tuantsingling, Point 10 in Pl. I
Trachytic Tuff	2.37	No. 5253	Nil*		Taichiahang, Point 7 in Pl. I
Tuffaceous sandstone	2.37	No. 5347	trace		
" "	2.39	No. 5348	trace		Tungshan, P. 3 in Pl. I.
Silicified Tuff, slightly Alun.	2.395	No. 4965	<1/10	less than 1%	Tsoupaokun f, Tafanshan.
Trachytic Tuff	2.47	No. 5256	Nil		Taichiahang.
Trachyte Porphyry	2.475	No. 5341	trace		Taichiahang, P. 26 in Pl. I
Alun. & Silic. Tuff	2.485	No. 5974	1/4±		S.W. of Chiaotzeting.
Alun. & Silic. Vesicular Tuff	2.49	No. 5345	>1/3		N. of Shihtsaoling.
Alun. & Silic. Trachytic Tuff	2.49	No. 4963	1/3±	24.18	Tsoupaokun m, Tafanshan.
Silicified Tuff	2.49	No. 5802	Nil		S.W. of Pichialao.
Alun. & Silic. Fine Tuff	2.51	No. 4964	1/3±	21.19	Tsoupaokun g, Tafanshan.
Alun. & Silic. Agglomerate	2.53	No. 4973	1/3-1/2	30.08	Tsoupaokun r, Tafanshan.
Alunitized & Silc. Trachyte	2.53	No. 4971	1/3	32.89	Tsoupaokun i, Tafanshan.
Alunitized Trachytic Tuff	2.575	No. 4966	>1/3	29.99	Tsoupaokun k_1, Tafanshan.
Alunitized Trachyte	2.58	No. 4968	>1/3	26.12	Tsoupaokun k_2, Tafanshan.
Alun. Trachyte Porphyry	2.58	No. 4970	<1/2	26.47	Tsoupaokun j, Tafanshan.
Alun. & Silic. Tuff	2.59	No. 4960	1/3±	35.18	Tsoupaokun d, Tafanshan.
Alun. & Silic. Tuff	2.59	No. 4959	1/2	19.87[2]	Tsoupaokun b, Tafanshan.
Alun. Trachytic Tuff	2.59	No. 4962	1/3-1/2	34.21	Tsoupaokun l, Tafanshan.
Alun. & Silic. Trachyte Porphyry	2.605	No. 5350	1/2		Point 22 in Pl. I.
Alun. & Silic. Fine Tuff	2.605	No. 4969	1/2	43.18	Tsoupaokun n, Tafanshan
Alunitized Tuff	2.61	No. 5631	<1/2	34.03	Point 16 in Pl. I.
Alun. Volcanic Breccia	2.61	No. 4967	<1/2	28.32	Tsoupaokun o, Tafanshan
Alunitized Agglomerate	2.615	No. 5346	>1/3	28.93	Tungshan, P_1, in Pl. I
Alunitized Trachyte Porphyry	2.615	No. 5634	<1/2	29.11	P_{15} in Pl. I.
Alunitized Fine Tuff	2.62	No. 5629	1/2	36.76	Yangshan, P_9 in Pl. I.
Alunitized Trachyte Porphyry	2.65	No. 5630	1/2	34.56	Tutang, P_6 in Pl. I.
Alunitized Trachyte Tuff	2.66	No. 5628	1/2	33.59	Tungshan P_1 in Pl. I.
Alunitized Trachytic Tuff	2.75	No. 4972	>1/2	47.49	Tsoupaokun h, Tafanshan.
Richly Alun. Fine Tuff	2.76	No. 4961	2/3	53.29	Tsoupaokun p, Tafanshan.

calculation, while as a matter of fact the partial replacement of potash by soda in alunite is a common phenomenon. Disregarding the small exceptions that may exist, three general rules can thus be obtained from this table: (1) The alunitized rock that has a higher alunite-content often possesses a greater specific gravity if the content of heavy minerals is rather small and the accompanied altered minerals are lighter than alunite, while the porosity of the different rocks is being assumed

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* There may be one or two crystals of alunite if not entirely absent.

[1] The % of alunite is computed according to the chemical formula, $K_2O.3Al_2O_3.4SO_3.6H_2$, but actually potassium is partly replaced by sodium, hence the % of alunite will be much higher if N_2O is included.

[2] This specimen has a N_2O content as high as 3.22, so that the % of alunite will be raised to 35.91 if N_2O is included.

to vary only within a certain limit. (2) The alunitized tuff, trachytic tuff and trachyte porphyry are heavier than their respective unaltered or less altered ones. (3) The more porous the rock is, the smaller the value of its specific gravity. Thus the most porous tuffaceous sandstone is the lightest rock in the table.

The specific gravity of the last specimen in the table approaches the value of a pure alunite since this sample has the highest alunite content and an abundant amount of quartz the latter is only slightly lighter than alunite.

C. RESERVE AND ECONOMIC VALUE OF THE DEPOSIT

As shown by their field occurrence the alumstone beds are more or less persistent downward in the dip direction to a certain depth but their thickness may vary to some extent. In the present estimate of ore reserve, the level of the adjacent plain which is about 25 meters lower than the Fanshantamiao (礬山大廟) is taken as the lowest limit of the ore sheets. It is believed that above this level, the ore is surely present and which can be economically extracted by the native method. The alumstone which has an alunite content above 30% is now mined by the native people, while those having a content between 30% and 25% although still workable, have not yet been exploited. The former may be called high- and medium-grade ore and the latter low-grade ore; the reserves of these two classes are to be calculated separately. Based on these principles the tonnage of the alumstone and the pure potassic alunite may be estimated as follows:

1) The first layer is a medium-grade ore, which has an average thickness of four meters, minimum length of 320 meters, an average specific gravity of 2.64 and a dip angle of 40°. The alunitized agglomerate which has an alunite content of 28.93% (No. 4967) and occurs just above the medium-grade alumstone is not included, because it is only 0.4 m thick and is not very long. The ore crops out on a slope 120 m higher than the plain, consequently its extension along the dip direction down to that depth is calculated to be 180 m. The reserve of the alunite rock is estimated as follows:

$$4 \times 320 \times 180 \times 2.64 = 608,256 \text{ metric tons}$$

The alunite content is 33.59% (No. 5628), therefore the reserve of pure alunite is:

$$608,256 \times .34 = 206,807.04 \text{ metric tons}$$

2) The second layer is 2 m. thick and 150 m. long, the dip angle of which is 40° to 45°. Its southern end has a local elevation (above the plain) of 190 m. and

its northern end 70 m; hence the vertical extension measured on the inclined surface of the layer is 200 meters. The alunite content and specific gravity are assumed to be the same as that of the first one. Then the total tonnage is:

Alunite rock $2 \times 150 \times 200 \times 2.64 = 158{,}400$ metric tons

Pure alunite $158{,}400 \times 0.34 = 53{,}856$

3) The alumstone of better quality of the third layer includes subdivision d, h, i, l, n, p, r and q of Tsoupaokun quarry, with a thickness of 28.5 meters and a mean alunite content of 38.34%. These values are obtained from the following calculations:

Thickness: $2(d) + 1.5(h) + 1.5(i) + 1.75(n) + 1.75(l) + 5(p) + 5(q) + 10(r) = 28.5$ m.

% of alunite for h: 47.49
l: 34.21
n: 43.18
p: 53.29

% of alunite for d: 35.18
i: 32.89
r: 30.08
q: 35.00

Average % of alunite: $(2 \times 0.3518 + 1.5 \times 0.4749 + 1.5 \times 0.3289 + 1.75 \times 0.3421 + 1.75 \times 0.4318 + 5 \times 0.5329 + 5 \times 0.3008 + 10 \times 0.35) \div 28.5 = 0.3834$. or 38.34%

But the average thickness may be reduced to 15 meters and alunite content to 35% for the whole length of 700 meters. Its dip angle is 60° and the mean specific gravity is 2.70. Its outcrop has a mean local elevation of 130 m. and the extension measured on the inclined surface of the layer is 150 meters. The reserve will be:

Alunite rock $15 \times 700 \times 150 \times 2.7 = 4{,}252{,}500$ metric tons

Pure alunite: $4{,}188{,}800 \times 0.35 = 1{,}488{,}375$

If the low-grade alunite-rock is also included, the thickness of this layers will be much more; as measured at Tsoupaokun quarry (Fig. 4) it is 56.2 meters with an alunite content of 34.57%. These two values are obtained by the following calculations:

Thickness and alunite % of various horizons: d, 2m, 35.18%; e, 18 m, 28%; h, 1.5 m, 47.49%; i, 1.5 m, 32.89%; j, 2 m, 26.47%; k, 4 m, 28%; l, 1.75 m, 34.21%; n, 1.75 m, 43.18%; o, 1.2 m, 28.32%; p, 5 m, 53.29%; q, 10 m, 35%, and r, 5 m, 30.08%.

Total thickness: 56.2 m

Average % of alunite: (2 × 0.3518 + 18 × 0.28 + 1.5 × 0.4749 + 1.5 × 0.3289
+ 2 × 0.2647 + 4 × 0.28 + 1.75 × 0.3421 + 1.75
× 0.4318 + 1.2 × 0.2832 + 5 × 0.5329 + 10 × 0.35 + 5
× 0.3008) ÷ 56.2 = 0.3457 or 34.57%

But the thickness and alunite content for the whole layer may be reduced to 40 m. and 30% respectively. The average specific gravity is 2.68, while both the length and the width measuring on the inclined plane remain the same as in the above case. The total tonnage of this layer will be:

Alunite rock: 40 × 700 × 150 × 2.68 = 11,256,000 metric tons
Pure alunite: 11,256,000 × 0.3 = 3,376,800

4) The medium- to high-grade ore of the fourth layer is 8 meters thick and 500 meters long, it has a dip angle of 32°, an alunite content of 37% (the % of No. 5629 is 36.76%) and a specific gravity of 2.61. Its southern end has a local elevation of 250 m. and that of the northern end 110 m; consequently the average extension measured on the inclined plane is 320 meters. The total tonnage is:

Alunite rock: 8 × 500 × 320 × 2.61 = 3,340,800 metric tons
Pure alunite: 3,340,800 × 0.37 = 1,236,096

The low-grade ore at Yangshan is 3 meters thick, with an alunite content of 26.56% (No. 5621) and a specific gravity 2.6. The thickness and the alunite content may be reduced to 1.5 m and 26% for the whole layer. Other conditions are same as the good ores. Then the reserve for the poor ore is as follows:

Alunite rock: 1.5 × 500 × 320 × 2.6 = 624,000 metric tons
Pure alunite: 624,000 × 0.26 = 162,240

5) The fifth layer is 1.5 m. thick and 300 meters long, having a dip angle of 35° and a specific gravity of 2.6. The alunite content is assumed to be 30%. It has an average local elevation of 75 meters and the extension measured on the inclined surface is 120 meters, Then the tonnage will be:

Alunite rock: 1.5 × 300 × 120 × 2.6 = 140,400 metric tons
Pure alunite: 140,400 × 0.3 = 42,120

6) The alunite rock of better quality of the sixth layer is 5 meters thick, and 1200 m. long, the average dip angle is 18°, specific gravity 2.65 and the alunite content 32%. The outcrop has an average local elevation of 100 m. and the extension on the inclined surface of the layer is 330 m. Thus the reserve amounts to:

Alunite rock: $5 \times 1200 \times 330 \times 2.65 = 5,247,000$ metric tons

Pure alunite: $5,247,000 \times 0.32 = 1,679,040$

If the low-grade ore is included in this layer, it has an average thickness of 40 meters and a length of 900 meters. The alunite content is reduced to 28%. But the specific gravity and the extension along the dip direction are still the same as in the above case. Then the total tonnage will be:

Alunite rock $40 \times 900 \times 330 \times 2.65 = 31,482,000$ metric tons
Pure alunite $31,482,000 \times 0.28 = 8,814,960$

RESERVE OF THE ALUNITE ROCK AND PURE ALUNITE IN
THE LUCHIANG DISTIRCT

No. of Layer	Alunite Rock > 25% alunite Metaic Ton	Pure Alunite Metric Ton
1st.	608,256	206,807
2nd.	158,400	53,856
3rd. (high grade ore)	4,252,500	1,488,375
3rd. (low grade ore)	7,003,500	1,888,425
4th.	3,340,800	1,236,096
Low grade ore at Yangshan	624,000	162,240
5th.	140,400	42,120
6th. (high grade ore)	5,247,000	1,679,040
6th. (low grade ore)	26,235,000	7,135,920
Grand Total	47,609,856	13,892,879

Therefore, the total reserve of pure alunite that can be extracted from the alunite rock containing more than 25% alunite amounts to 13,892,879 metric tons, in which 4,664,174 tons are obtained from the high grade ore containing more than 30% of alunite. The deposit was discovered about 400 years ago, and the amount of pure alunite already taken away may be assumed to be 1,000,000 tons, so that the net reserve is about 12,892,879 tons, or in round number nearly 13 million tons. The potash content in alunite as calculated from its chemical formula is 11.4%, consequently it will yield about one and a half million tons of potash theoretically. According to the experience of the alum manufacturers of Fanshan, every 100 catties of rich alumstone will yield 25 catties of alum as maximum or to say in round number about 20%. If we take 33.3% as the average yield of alum from pure potassium-alunite, a total of about four million tons of pure alum may be produced from the entire deposit and this will in turn worth 50 to 200 millions dollars. The quantity of alum produced would be nearly doubled if the roasted and dehydrated alunite should be extracted with acidified water containing 10% of H_2SO_4 instead of pure water.[1]

According to the microscopic study of the specimens collected, rocks located far away from the alumstone layers may contain alunite up to 30% or so (as No. 5350, 5345, 5979 and others), hence new alumstone layers rich enough for the manufacture of alum may be discovered or the present known alumstone beds may be extended when more detailed investigation of this area is made.

VI. ORIGIN OF THE DEPOSIT AND A STUDY OF THE ALTERATION OF THE ROCKS

As has already been stated in the foregoing chapters, both volcanic and intrusive rocks have undergone five kinds of alteration, namely, silicification, alunitization, kaolinization, sericitization and the introduction of iron in the form of hematite. They are indicated by the presence of quartz, alunite, kaolinite, sericite and hematite respectively, which are obviously of secondary origin[2] as shown by their mode of occurrence as well as microscopic textures. Especially important are the processes of silicification and alunitization; the microfelsitic aggregate of quartz forms the most eminent feature in practically all thin slides of the altered rocks studied, while alunite occurring in any forms makes also a conspicuous appearance in the thin sections. Certain rock even has a silica content as high as 89.74% and another one may contain pure potassic alunite up to 53.29%. Kaolinite, sericite and hematite are common in all rock samples, though seldom abundant. In a few exceptional cases the iron content is extraordinarily high so as to form a poor iron ore. The fact that the tuff rock in the region from Luchiawa and Shihtsaoling westward to Hsiaofanshan is much more altered than the rocks of other localities testifies the hypothesis that the more soft and easily permeable rocks are more susceptible to such kind of alteration.

The relative order of crystallization of the different altered minerals can be detected in several thin slides of the rocks studied. Quartz was crystallized either simultaneously with or a little earlier than the alunite, which was followed by kaolinite and sericite while hematite was the latest one formed. Two stages of alunitization have been recognized microscopically, the first one is represented by a general alunitization of the rocks with the formation of workable alumstone beds, while the second one is manifested by small veinlets of alunite often accompanied by hematite

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[1] The method for the manufacturing of alum in the Fanshan area will be briefly stated in a later chapter.

[2] Of coarse there are primary quartz and hematite in certain rocks.

or quartz; this process is evidently not important and may be even later than kaolinization. But the time intervals between the various stages of crystallization seem to be very short, as is indicated by the close association and intimate relationships between those altered minerals. Thus it may be safely concluded that these five processes of alteration have been produced by the same agent and perhaps under the similar conditions.

Now let us consider the origin of the alunite mineral, the result of which may serve as a key to solve the questions of the other altered minerals. Alunite is usually known as a secondary mineral in aluminous rocks altered by cold sulfated solutions or it is produced by sulphurous solutions or vapors affecting feldspathic rock with or without the addition of potassium and aluminum and at a rather low temperature. The solution is most probably introduced along certain lines of weakness in the rocks. But where and how did the sulphurous vapor or solution or the sulphate water come from in the Fanshan area?

There are altogether three hypotheses[1] explaining the possible sources of sulphuric acid or sulphate ions in the solution that is essential for the formation of alunite.

The first hypothesis is that the alunitization was effected by sulfated meteoric waters percolating downward from masses of oxidizing sulphides, chiefly pyrite. Although small pyrite grains often partly altered into a milky white to yellowish white amorphous substance, probably a certain kind of iron sulfate, have been abundantly found in a dark grey ignous rock, forming xenolith in a pinkish and greyish white banded trachyte (No. 5332), the outcrop of such a rock has not yet been met with. In the microgranite there occurs only two or three small, fresh pyrite grains. In all other rocks we have never found any trace of pyrite minerals. Hence the possibility of the sulphuric acid being derived from the oxidation of pyrite can perhaps be excluded in the present case.

The second hypothesis is that the sulphur dioxide that emitted from the fumaroles or craters in the time of ancient volcanic eruption may be oxidized to sulfuric acid and then acted upon K-Al-bearing mineral in the lava or tuff previously formed to produce alunite. If such was the case, we should expect to find alunite

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[1] See: A. B. S Buttler and H. S. Gale: Alunite, a newly Discovered Deposit near Marysvale, Utah. Bull. 511, U.S.G.S. 1912
B. P. L. Ransome: Geology and Ore Deposits of Goldfield, Nevada, Prof. Paper 66, U.S.G.S. 1905 pp. 129-133.
C. W. Cross & A.C. Spencer: Geology of Rio Mountain, Colorado. 21th Annual Rept. U. S. G. S. 1909, pt. 2, pp. 92-94, and others.

a more common mineral constituent in the volcanic rock than experience indicates, and only the volcanic rock itself, should be alunitized immediately after its formation; and furthermore, there should be some trace of pyrite or other sulfur-containing minerals in the volcanic rocks. But all the facts are just contrary to such suppositions. It is obvious that this suggestion fails to explain the origin of alunite in the area in discussion.

The third hypothesis is that the sulfur dioxide carried in the hot solution emanated from some intrusive body below might be oxidized to sulfuric acid on its way upward to the surface and affected certain potassium-aluminum-rock to form the mineral alunite. From the facts that both intrusive[1] and extrusive rocks are alunitized, and that richly alunitized beds are usually closely related to the intrusive body, the central part of which containing frequently some pyrite grains, suggest that the intrusive magma was the most probable source of sulfate solution which came up immediately or not long after the instrusion. Similar conclusion was reached by Mr. L. F. Yih in his study on the alunite deposit in Pingyang district, southeastern Chekiang[2]. Alunite is also found in some abundance in northern Tangtu district, Anhui, in certain volcanic rocks not very far from the contact with the dioritic intrusion[3]. Therefore, the writers dare to conclude that the alunitization of the acid lava is simply a phase of alteration produced by the igneous after effect of the acid intrusion.

Whether there were any alumina or potash in the sulfate-bearing solutions is not certain. As shown by the microscopic study of rock specimen No. 4967 there exist evidently two kinds of feldspars, one of which, an orthoclase with potassium, has been almost entirely changed to alunite; the other one, probably a plagioclase containing sodium and calcium is largely altered to kaolin and sericite, in which no or litttle alunite can be found. This fact indicates that there was but little amount of potash and alumina in the sulfate-bearing solutions, so that minerals lacking of potassium such as plagioclase could not be easily replaced by alunite during the stage of alunitization.

Since all the intrusive rocks are porphyritic in texture and usually medium-grained, they belong to the hypabyssal class and consequently formed under a fairly high temperature and pressure. The condition for the formation of alunite must be at much shallow depth, though the exact values have never been definitely determined.

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[1] But the intrusive rocks are usually less alunitized

[2] Mem. Nat. Res. Int. of Geol. No. XI.

[3] Mem. Geol. Surv. China, Series A, No 13, pp. 16-18, 42-43, 45. (English text)

It seemed that the process of alunitization was carried on under a comparatively static condition, as the feldspar phenocrysts that were replaced partly or wholly by either alunite or quartz, usually still retained their crystalline outline, and, furthermore, nearly all the original textures in the volcanic rocks have been preserved by the alumstone.

While both silicification and sericitization can be produced under various conditions, and hematite and kaolinite may be formed under widely variant circumstances it is evident that in the Fanshan area they are all of hydrothermal origin and were formed perhaps under the same conditions as that of alunite. The reasons have already been given in the above and will not be repeated.

In a word, the alteration of the rocks in the vicinity of Fanshan is essentially the result of hydrothermal action following the granitic and dioritic intrusions. As indicated by the presence of kaolinite and the occasional association of fine sericite scales together with the hypabyssal nature of the intrusions, a mesothermal to epithermal origin of the ascending solution may possibly be assumed. Such a condition is very similar to that of Tangtu, Kiukiang and Nanking Area, but there the process of alunitization is less important or even absent and the formation of iron deposits was the most important task accomplished. In the area under discussion only alunitization, without the formation of iron deposits in workable size formed the sole prominent alteration.

In summarizing up all the facts obtained from field and microscopic studies, the following events may be recognized: (1) Successive layers of lava were poured out, with several intervals of quiescence during which the lava lost most of their heat and partly eroded by exogenic agents. (2) The next event was the intrusion of a granitic magma whose margins differentiated into a porphyritic rock with accompanied dikes or irregular forms of diorite porphyry intruding both the volcanic formation and the older rocks. The intrusive as well as the country rock became fissured as a result of readjustment of the rocks due to cooling and contraction. (3) Along the fissures hot solutions derived from the same magmatic source as the intrusive rock rose successively and interruptedly and usually introduced into the more soft, loose and easily soaked tuffaceous beds. Replacement between the solutions and the country rocks made the appearance of secondary quartz, alunite, kaolinite, sericite, hematite and other minerals in the country rocks. The rocks were thus silicified, and a few rock layers were richly alunitized and then changed to alumstone beds of irregular thickness. After the process had been carried on for a certain period of time, fissuring and filling up by alunite, hematite and also silica through the already altered rock took place, which account for the formation of small veinlets of alunite of the second generation and the iron ore. The solution was highly heated and probably under considerable pressure at the time of starting its journey upward, but as it passed into the cooler overlying rock and at a time when alunite deposit began to be formed both the temperature and the pressure were greatly reduced, so that the deposits in question belongs eventually to mesothermal or epithermal type.

VII. ALUM INDUSTRY

According to the informations of the native people, the alunite-rock of the Fanshan region began to be exploited at the beginning of Ming Dynasty. Later on, the two well-known towns, Tafanshan and Hsiaofanshan were grown up and become now the only important alum-producing center in Anhui.

The only use of the stone at present and in the past is in the manufacture of alum, which is used for purifying the drinking water and constituting one of the common household necessities in China since long ago. It was told that the alum industry was very flourishing in the past and many people have made their fortune in this business. But now it is in a period of depression. Many quarries have been abandoned and many kilns stopped working so that hundreds of workmen became unemployed in the last few years. At present, there are altogether seven quarries under working and twenty local dealers, each possessing one or more kilns in the neighbourhood of the two towns mentioned above. The capital of a dealer varies from four hundred to four or five thousand dollars and most of the kilns work only four or five months in a year.

The method for the manufacture of alum may be briefly stated here. The rock pieces taken from the quarries are at first roasted in the kilns—usually thousands of catties at a time, the exact number is fixed by the size of the kilns—to red hot by straws for three or four days, the burned stones are then crushed into small pieces and transferred into the pits that have been previously dug into the ground surface. A definite quantity of water is added into the pits for every ten days and ten times will be usually enough. Then the pits should be covered by earthy material—the waste or residue that comes from the alum-dissolving kettle is best suited—for fifty or sixty days until a soft and plastic mass is resulted. Such white powders are boiled with a proper quantity of pure water in the large iron kettles so that all the soluble substance may be extracted. The insoluble material left on the filtering cloth is called residue or waste, which may or may not be further extracted, while the greenish yellow filtrate, i. e., the clear solution, is then infused into large earthern jars for evaporation and precipitation. After four or five days large and beautiful isometric alum crystals are obtained on the bottoms and walls of the jars. It is then packed in the barrels made of bamboo and are ready for the market, each barrel containing 150 catties of alum. On the average, one picul i. e. one hundred catties of alumstone will produce twenty or more catties of alum.

As was told by the local dealers the average annual production of alum is 30,000 to 40,000 barrels i. e., 2679 tons to 3571 tons, with a value of about 120,000 to 160,000 dollars. Part of the alum is first brought to Wuhu and then shipped to other ports. The amount of alum that exported from Wuhu from 1924-1933, as was recorded by the Chinese Maritime Customs Returns is as follows:

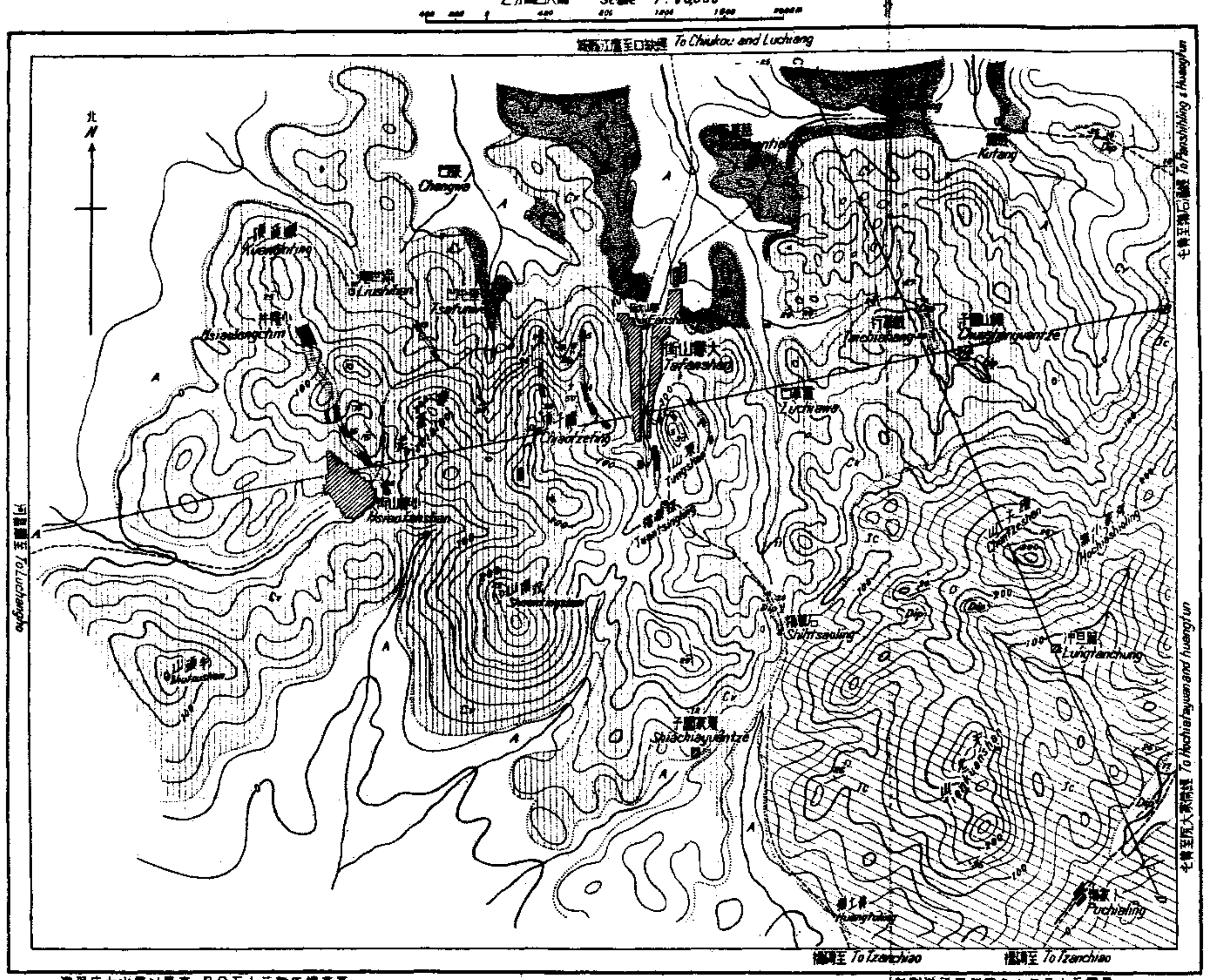
	Piculs	Tons		Piculs	Tons
1924	3,011	179.2	1929	2,486	147.9
1925	1,655	98.5	1930	7,365	438.4
1926	2,865	170.5	1931	6,332	376.7
1927	1,773	105.5	1932	40	2.4
1928	1,902	113.2	1933	115	6.8

The sudden drop of the alum export at Wuhu in 1932 and 1933 is probably due to the conflict between the alum-producers of Fanshan and the alum-purchasing companies in Wuhu.

第一版
Plate I

安徽廬江礬礦地質圖
GEOLOGICAL MAP OF THE LUCHIANG ALUNITE DEPOSITS, ANHUI

縮尺四萬分之一 Scale 1:40,000



等高線距離二十五公尺 高度以礬山大廟為準
Contour interval 25 meters. The elevation of Fanshantamiao
is assumed to be zero

民國二十二年十月陳愷程裕淇測製
Surveyed in October, 1933, by K. Chen and Y. C. Cheng

圖例
Legend

大路
Road

1,2,3, etc
文中詳細敘述之岩石標本產地
Locations of rock specimens described in the text

未開採之礬石層
Alunite beds not yet exploited

已開採之礬石層
Exploited alunite beds

Dip
閃長斑岩
Diorite porphyry

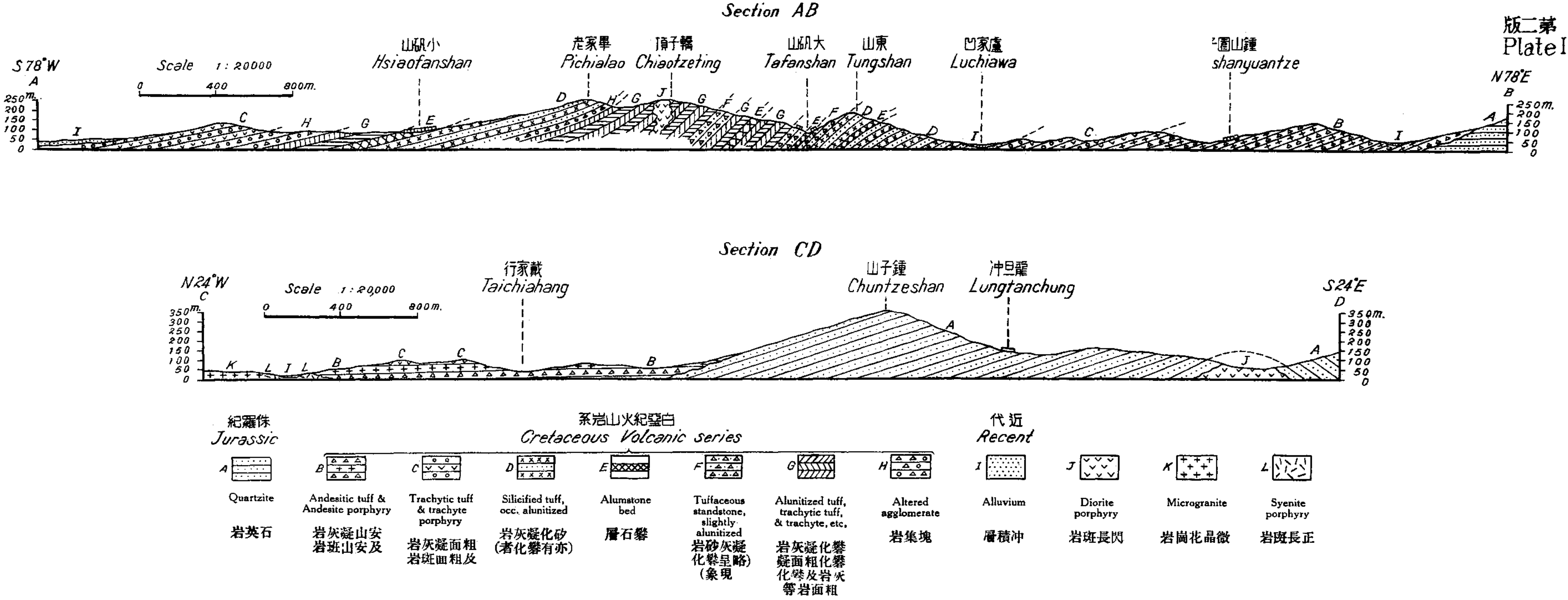
微晶花崗岩
Micro-Granite
(Changed to syenite porphyry toward the margins)

A
近代 Recent
沖積層
Alluvium

Cv
白堊紀 Cretaceous
火山岩系
Volcanic Series

Jc
侏羅紀 Jurassic
磚子山層
石英岩
Chuantzeshan Series
Quartzite

第二版
Plate II


Section AB
S 78° W
A
N 78° E
B
Scale 1 : 20000
0 400 800m.
250m. 200 150 100 50 0
小礬山 Hsiaofanshan
畢家老 Pichialao
轎子頂 Chiaotzeting
大礬山 Tafanshan
東山 Tungshan
盧家凹 Luchiawa
鍾山圓 shanyuantze
I C H G E D H G J G F G E G E F D E D I C B I A
Section CD
N 24° W
C
S 24° E
D
Scale 1 : 20,000
0 400 800m.
350m. 300 250 200 150 100 50 0
戴家行 Taichiahang
鍾子山 Chuntzeshan
龍旦沖 Lungtanchung
K L I L B C C B A J A
侏羅紀 Jurassic
白堊紀火山岩系 Cretaceous Volcanic series
近代 Recent
A Quartzite 石英岩
B Andesitic tuff & Andesite porphyry 安山凝灰岩及安山斑岩
C Trachytic tuff & trachyte porphyry 粗面凝灰岩及粗面斑岩
D Silicified tuff, occ. alunitized 矽化凝灰岩(亦有礬化者)
E Alumstone bed 礬石層
F Tuffaceous standstone, slightly alunitized 凝灰砂岩(略呈礬化現象)
G Alunitized tuff, trachytic tuff, & trachyte, etc. 礬化凝灰岩礬化粗面凝灰岩及礬化粗面岩等
H Altered agglomerate 集塊岩
I Alluvium 沖積層
J Diorite porphyry 閃長斑岩
K Microgranite 微晶花崗岩
L Syenite porphyry 正長斑岩

Explanation of

Plate III

PLATE III 第三版

Fig. 1. Tsoupaokun quarry, west of Tafanshan. Looking west.

第一圖 大礬山珠寶坑。

Fig. 2. Another view of Tsoupaokun quarry, looking northwest.

第二圖 大礬山珠寶坑礬石礦坑之又一景。

Fig. 3. A distant view of Tungshan (T.), Chiaotzeting (C.), and Tsoupaokun quarry (T. P.) and the northern part of Tafanshan town. Looking west.

第三圖 東山轎子頂珠寶坑及大礬山街北部之遠景向西照。

Fig. 4. Chuntzeshan, a hill composed of Jurassic quartzite, as seen from the northern slope of Tienkuanshan.

第四圖 鍾子山乃由侏羅紀石英岩所組成者。

Fig. 5. Abandoned quarries (Q) near Huashan, E. of Hsiaofanshan. Notice the maturely dissected topography.

第五圖 花山附近已廢棄之礬石礦坑 (Q). 並示壯年地形。

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Explanation of Plate IV

PLATE IV 第四版

Fig. 1. Tienwutang quarry, N. of Hsiaofanshan.

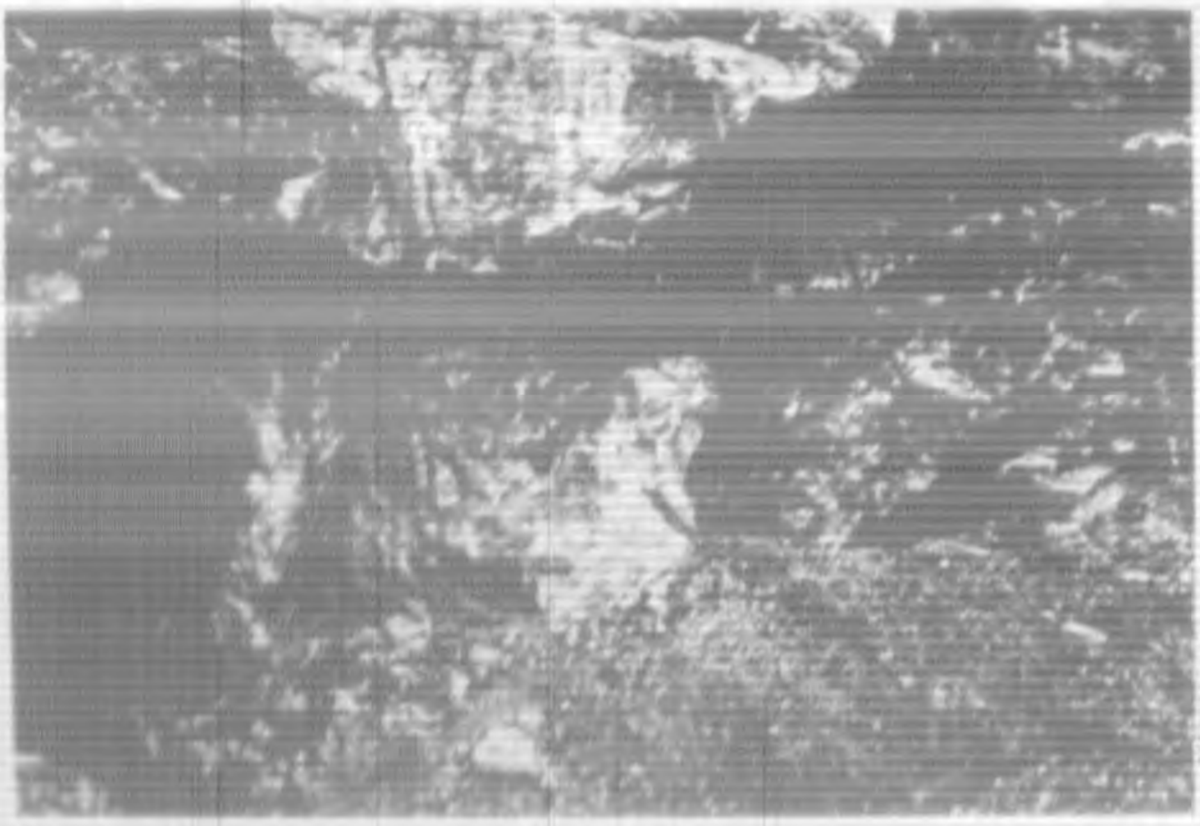
第一圖 小礬山天屋塘採礬石之礦坑。

Fig. 2. An abandoned quarry near Hsiaofanshan.

第二圖 小礬山附近久已廢棄之礬石礦坑。

Fig. 3. A part of Hsiaofanshan town, looking south. The white smoke comes from the alunite-roasting kilns.

第三圖 小礬山鎮之一部,有白煙處卽爲燒礬石之窰。



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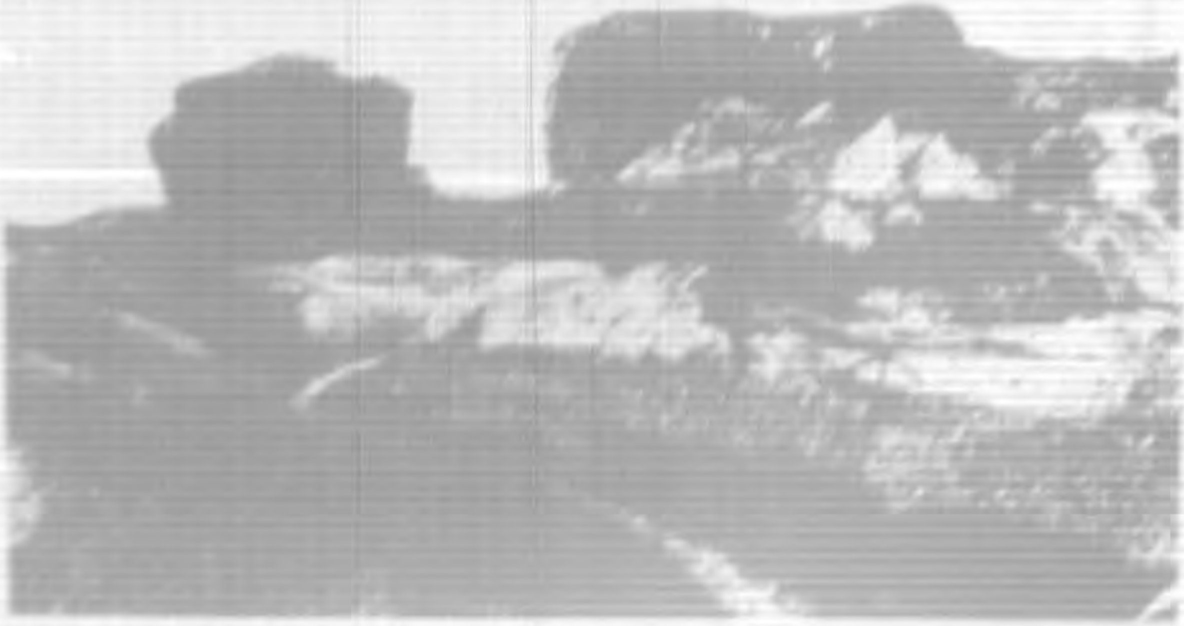

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Explanation of

Plate V

PLATE V 第五版

Fig. 1. Alunitized agglomerate from the eastern slope of Tungshan, × 27, parallel nicols. Only a portion of the pebble is shown here. Feldspar phenocrysts (white and rectangular) and groundmass partly replaced by fine alunite scales (white scales) are cut across by a veinlet composed of alunite (white) and hematite (black).

第一圖 礬化塊集岩, 平行偏光鏡下放大二十七倍。標本採自東山東坡。圖示礫塊之一部, 長石斑晶 (白色. 長方形) 及基質, 局部變成明礬石鱗片 (白色), 叉爲明礬石及赤鐵塊組成之細脈所穿割。

Fig. 2. Ditto. × 42, parallel nicols. A feldspar phenocryst (in the center) already replaced by fine scales (white) of alunite is further cut through by a veinlet composed of hematite (black) and alunite (white).

第二圖 同上, 平行偏光鏡下放大四十二倍。一長石斑晶 (在圖之中部), 已局部變成鱗片狀明礬石, 叉爲明礬石及赤鐵礦合成之細脈所透穿。

Fig. 3. Richly alunitized fine tuff from Tsoupaokun, Tafanshan. × 42, cross nicols, showing a tuffaceous rock a greater part of which is replaced by fine scales of alunite (white). Notice the irregular white patches aggregated by the alunite scales.

第三圖 礬化甚深之細凝灰岩, 直交偏光鏡下放大四十二倍。標本採自大礬山珠寶抗。圖示一凝灰質岩石大部爲鱗片形明礬石 (白色) 代換之狀, 後者偶或結集成不規則之形體。

Fig. 4. Alunitized volcanic breccia from Tsoupaokun, Tafanshan. × 27, parallel nicols. Showing the replacement of a clastic rock by alunite. The black portion on the left is a pebble, being only slightly alunitized. The grey portion on the right is the matrix, which is largely replaced by acicular and scaly alunite (white). Notice the abundance of alunite needle and prismatic plates along the contact between these two parts.

第四圖 礬化火山角礫岩, 平行偏光鏡下放大二十七倍。大礬山珠寶抗產。在左之黑色部分乃一礫塊, 僅有小部爲針狀明礬石所代換; 右邊之灰白色部份乃黏合質, 含有針狀及鱗片狀之明礬石甚多。二者接觸處, 明礬石之聚積最爲豐富。

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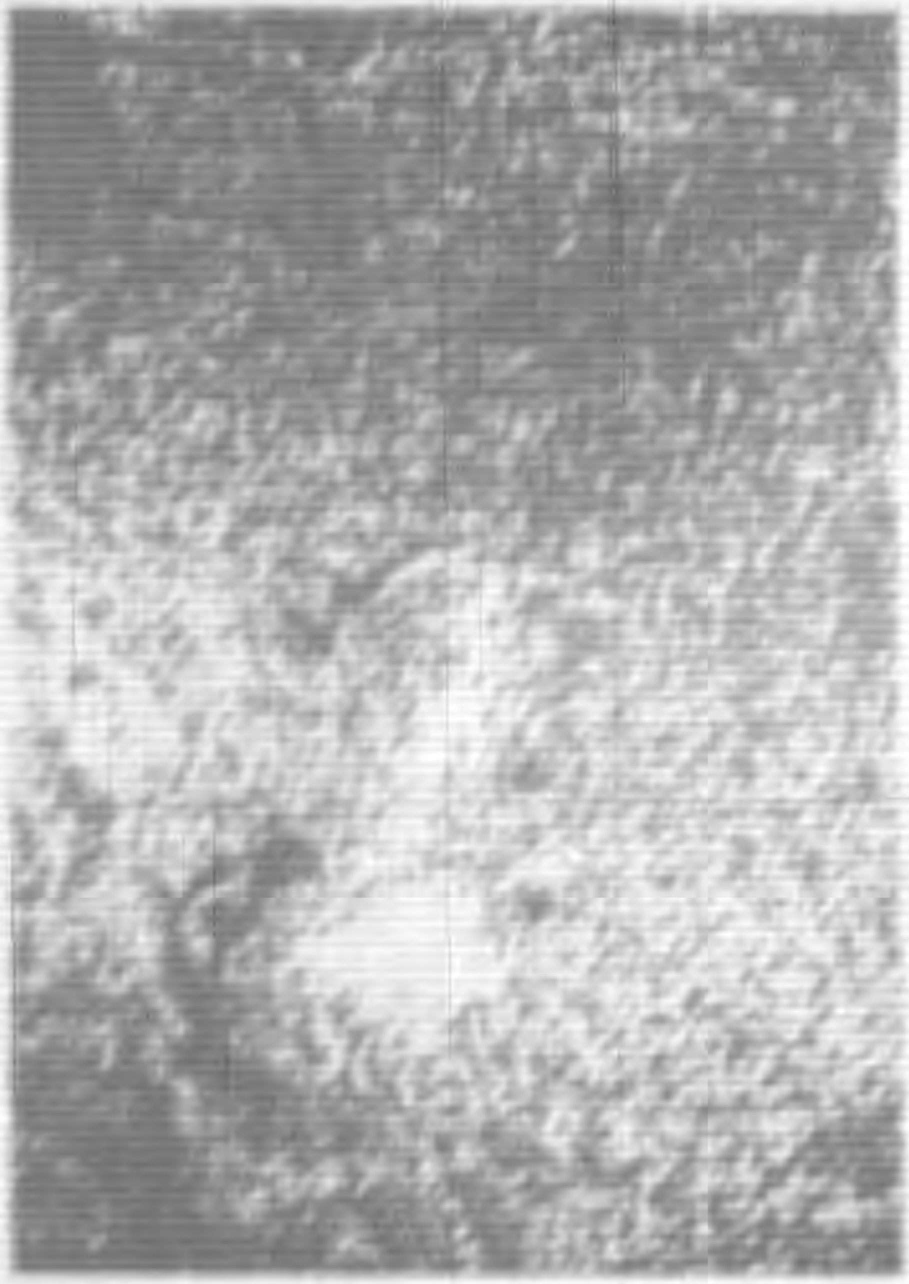

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Explanation of

Plate VI

PLATE VI 第六版

Fig. 1. Alunitized and silicified tuff. Tsoupaokun, Tafanshan. × 42, parallel nicols. A portion of the fragmentary elements is shown here. The rectangular feldspar phenocryst is replaced partly by alunite, which occurs in the form of long and narrow prisms. Note the clusters of fine quartz and scaly alunite in the matrix.

第一圖 礬化及矽化凝灰岩. 平行偏光鏡下放大四十二倍。採自大礬山西珠寶坑. 圖示石屑之一部, 其中下部略呈長方形之礦物, 乃長石斑晶, 然已大部爲細長晶體之明礬石所替換. 基質內多爲石英之團集體及明礬石鱗片。

Fig. 2. Alunitized and silicified fine tuff, from Tsoupaokun, Tafanshan. × 42 cross nicols. A large spinning-spindle-shaped crystal and many acicular crystals of alunite are embedded in a fine groundmass, which consists chiefly of microcrystalline quartz. This large crystal is an aggregated body of many acicular alunite, all having a general optical orientation.

第二圖 礬化及矽化細凝灰岩, 直交偏光鏡下放大四十二倍。標本採自大礬山西珠寶抗。基質內多爲微晶質之石英, 並含有細明礬石, 後者除一大梭形晶體外, 其他皆成細針狀。此大晶體乃由多數小針狀體合組而成, 具有均一之光學性。

Fig. 3. Alunitized diorite porphyry, × 42, parallel nicols. In the valley just east of Yangshan. A large feldspar phenocryst has been entirely replaced by alunite, which occurs in large massive form with fractures in the central part and irregular fragments or fine scales on the borders.

第三圖 礬化閃長岩. 平行偏光鏡下放大四十二倍。標本採自羊山以東溝中。一長石斑晶已完全爲明礬石所代換, 其中部呈塊狀, 並有裂縫, 四週乃不整齊之小塊形。

Fig. 4. Ditto, cross nicols. The position of view is slightly changed.

第四圖 同上, 直交偏光鏡下之像。照片之位置, 略經改易。

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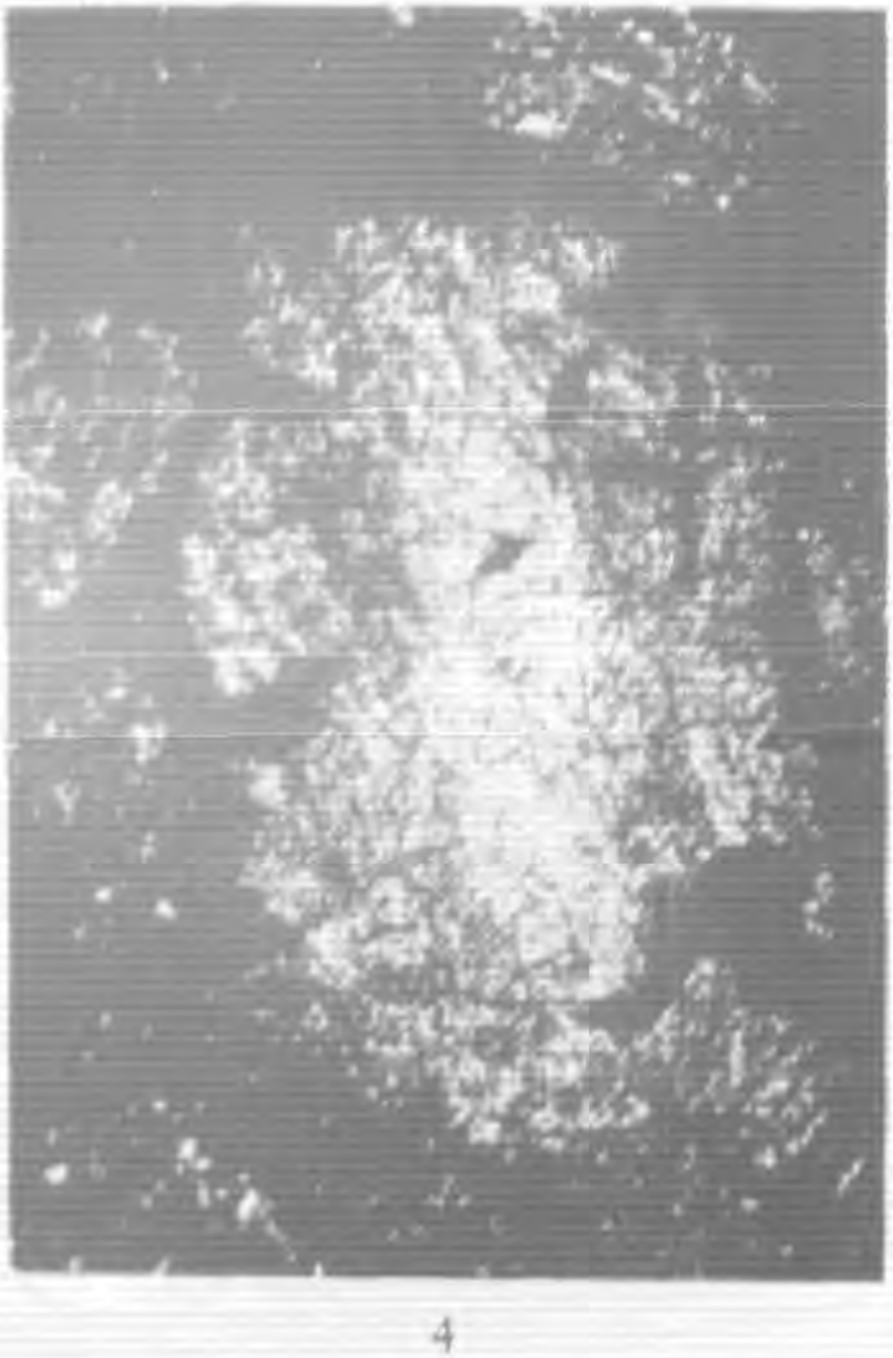

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Explanation of

Plate VII

PLATE VII 第七版

Fig. 1. Alunitized and silicified breccia or agglomerate from Tsoupaokun, Tafanshan. × 42, cross nicols. The curved fracture in the lower part of this photo is the contact line between a pebble and the matrix. The portion situated above this line is the pebble, which is a porphyritic rock being mainly replaced by alunite scales and further cut through by two veinlets (V.) composed of alunite (white) and hematite (black).

第一圖 礬化及矽化之角礫岩或塊集岩，直交偏光鏡下放大四十二倍。標本採自大礬山珠寶抗。 照片下部之裂縫乃礫塊及黏合質之分界線，其上卽斑狀岩塊，大部已爲明礬石所代換，而復被二明礬石及赤鐵礦組成之細脈(V.) 所割切。

Fig. 2. Same rock as in Fig. 1. × 42, parallel nicols. A part of the rock fragment is shown here. The rock already alunitized is further traversed by veinlets of alunite and hematite.

第二圖 同上，爲平行偏光鏡下之像，惟照片之位置已經移動。圖中所示者乃礫塊之一部，業已礬化，而又爲明礬石及赤鐵礦合成之細脈所透割。

Fig. 3. Ferruginous silicified fine tuff (a poor siliceous iron ore) from Chiaotzeting, × 42, parallel nicols. Showing the clusters of microcrystalline quartz traversed by irregular veinlets of hematite (black). Vesicles (V.) are abundant.

第三圖 含鐵矽化細凝灰岩 (矽化劣質鐵塊)，平行偏光鏡下放大四十二倍。標本採自橋子頂。微晶質之石英團集體，爲不規則之赤鐵礦脈所穿侵。氣孔(V.) 甚多

Fig. 4. Alunitized agglomerate from the eastern slope of Tangshan, × 42, parallel nicols. Only a portion of the pebble is shown here. The rectangular feldspar phenocryst is replaced by numerous irregular fragments of alunite.

第四圖 礬化塊集岩。採自東山東坡。圖中所示者乃礫塊之一部，長石斑晶多已變成不整齊之小塊形明礬石。

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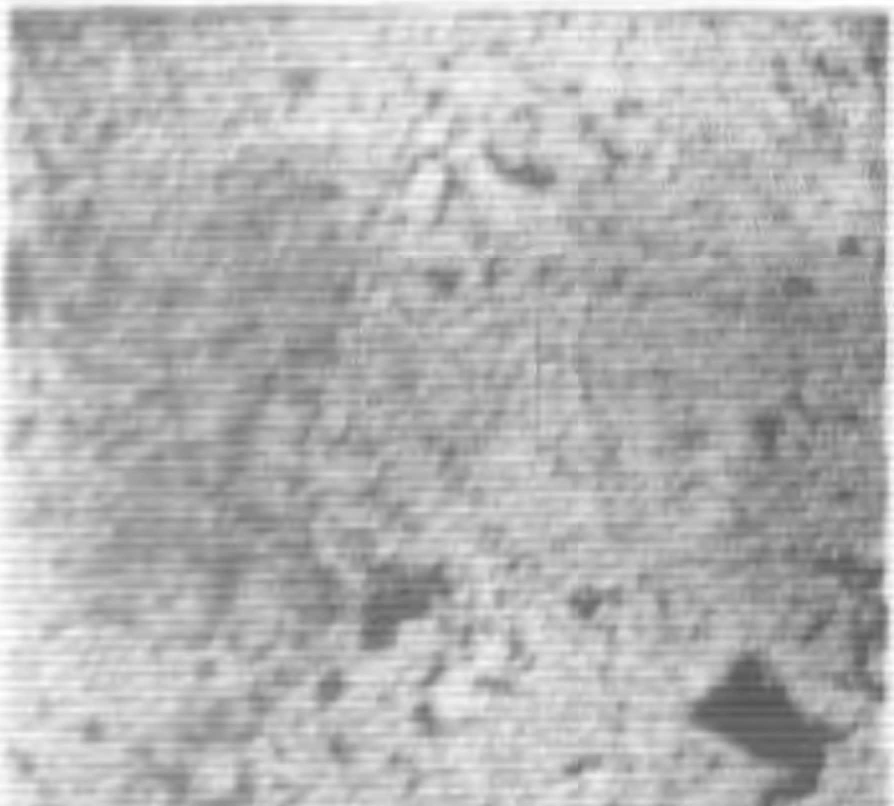

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Explanation of

Plate VIII

PLATE VIII 第八版

Fig. 1. Alunitized and silicified fine tuff from north of Shihtsaoling, × 42, cross nicols. Numerous alunite crystals are embedded in a groundmass composed chiefly of fine quartz.

第一圖 礬化及矽化之細凝灰岩, 直交偏光鏡下放大四十二倍。標本採自石曹嶺北。多數細針狀明礬石散佈于基質中, 後者多由石英細粒所組成。

Fig. 2. Silicified tuff, slightly alunitized. × 42, cross nicols. Tsoupaokun, Tafanshan. Few needle-shaped alunite crystals are embedded in a groundmass composed of fine quartz, hematite and others. Note the vesicle on the upper right corner being partly filled by alunite. Both quartz and alunite are secondary minerals.

第二圖 略呈礬化之矽化細凝灰岩, 直交偏光鏡下放大四十二倍。 標本採自珠寶坑。一二針狀明礬石散佈于由石英及赤鐵塊等組成之基質內。圖之右上角有一氣孔, 已有一部爲明礬石所塡充。此處之明礬石及石英, 皆爲次生礦物。

Fig. 3. Alunitized and silicified tuff from Tsoupaokun, Tafanshan. × 42, cross nicols. Alunite needles and laths are scattered in a groundmass composed chiefly of quartz.

第三圖 礬化及矽化之凝灰岩, 直交偏光鏡下放大四十二倍。標本採自大礬山珠寶坑。針狀及板片狀之明礬石結晶體, 散佈于基質內, 後者多由石英小塊組合而成。

Fig. 4. Alunitized volcanic breccia from Tsoupaokun, Tafanshan. × 42, cross nicols. A pebble of porphyritic nature is shown here. The tabular feldspar phenocryst in the center is altered mainly to alunite, either in the form of short plates or long and narrow prisms. The groundmass is composed of abundant microcrystalline quartz but a small amount of alunite.

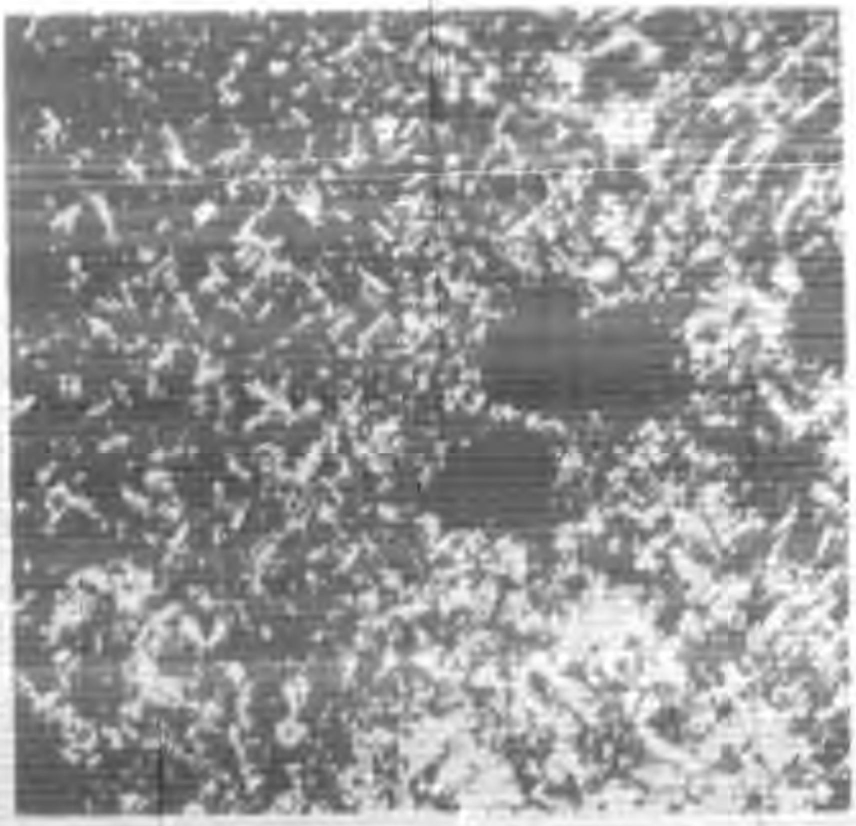
第四圖 礬化火山角礫岩, 直交顯微鏡下放大四十二倍。大礬山珠寶坑產。圖中所示者乃一斑狀岩塊, 中部之長方形長石斑晶, 幾已全部變爲明礬石, 或成細長粒狀晶體, 或成短闊板狀。至基質多爲微晶質之石英, 亦有明礬石片, 然其量甚少。

Fig. 5. Alunitized and silicified tuff from Tsoupaokun, × 42, cross nicols. A portion of the matrix is shown here. It is composed of microcrystalline quartz with disseminations of scaly alunite.

第五圖 礬化及矽化之凝灰岩, 直交偏光鏡四十二倍。標本採自大礬山珠寶坑。圖示黏合質之一部, 微晶石英及鱗片狀明礬石互相混雜, 不易分清。

Fig. 6. Alunitized and silicified fine tuff from Kuniupei, Tafanshan. × 42, cross nicols. Alunite (white) occurs in massive forms.

第六圖 礬化及矽化之細凝灰岩, 直交偏光鏡下放大四十二倍: 標本採自大礬山嶺北古牛背。圖示大塊狀之明礬石結晶。



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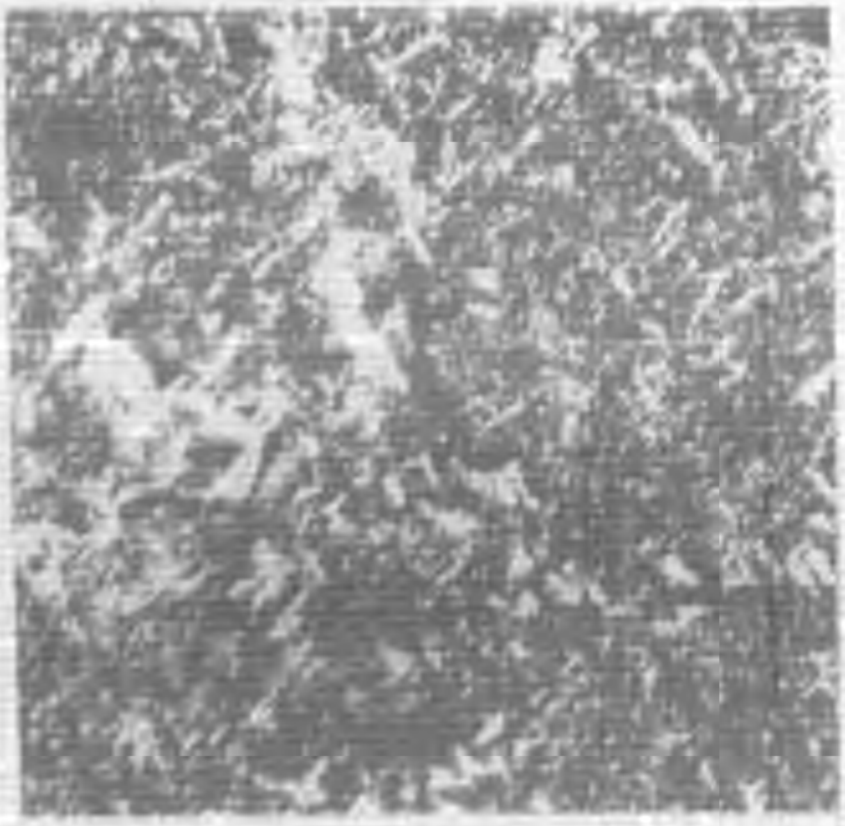

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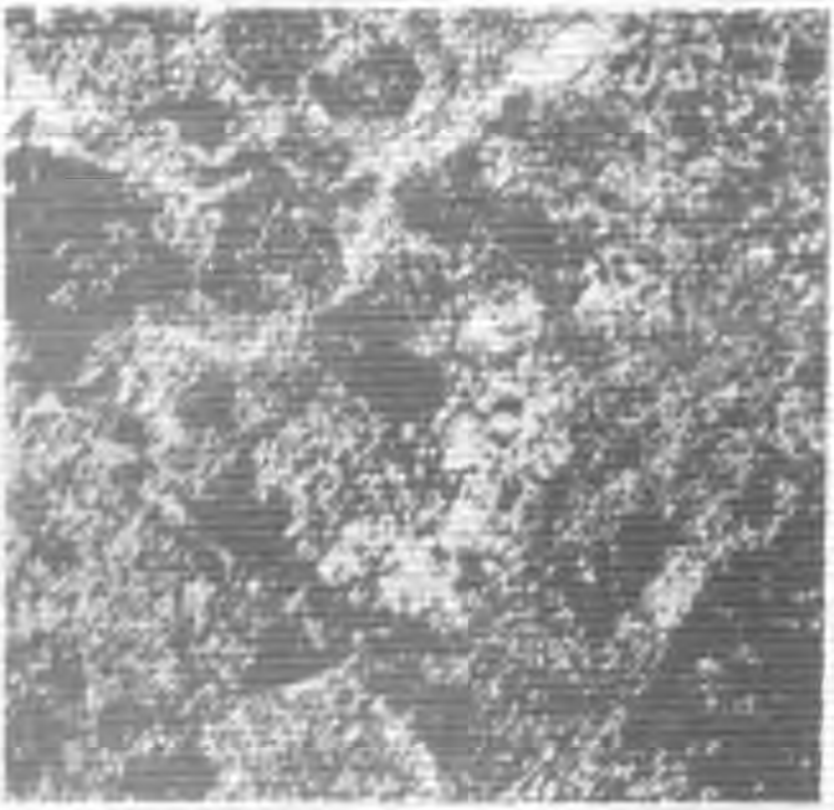

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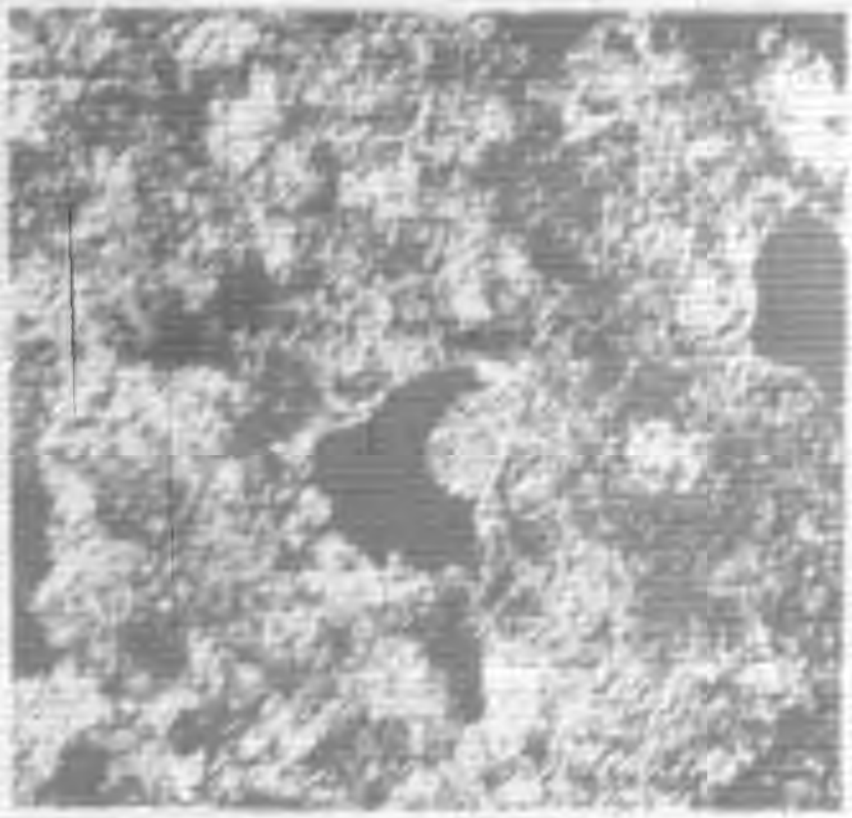

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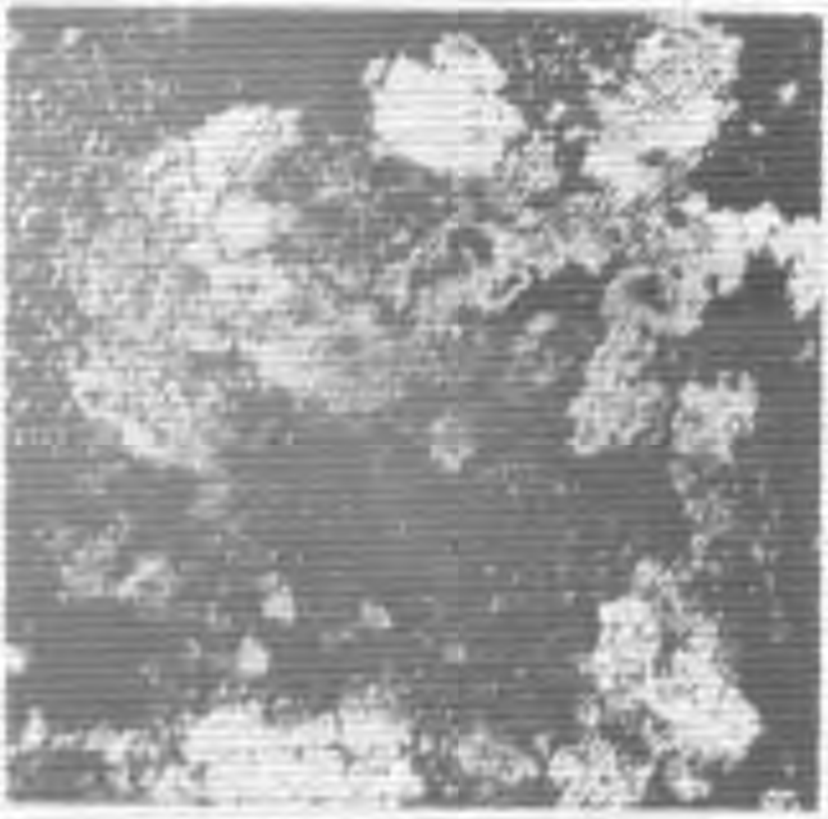

6

THERMAL DECOMPOSITION OF ALUM

By

YUEPEH C. H. YOUNG AND K. Y. KING

CONTENTS

I. INTRODUCTION

In a previous paper, King and Hsiao[5] determined the optimum conditions for the extraction of alum from Pingyang alumstone containing 74.70% of pure alunite. It is shown also that by the addition of K_2SO_4, the yield of alum can be increased from 50.30% to 73.70%. Because of the ease with which alum can be purified and the consequent elimination of the impurities which are present in the original alumstone, pure alumina can therefore be prepared by the thermal decomposition of alum. Owing to the wide difference in the decomposition temperatures of $Al_2(SO_4)_3$ and K_2SO_4, $Al_2(SO_4)_3$ can be easily splitted into Al_2O_3 and SO_3 at a certain definite temperature without effecting K_2SO_4 to any extent at all. Furthermore, with such a great solubility difference between these two compounds toward water, K_2SO_4 can be separated from the calcined Al_2O_3 and K_2SO_4 mixture at ease where Al_2O_3 remains behind as a pure but insoluble product.

With these common and well established facts on hand, it looks as if the thermal decomposition of alum which is obtainable from alumstone§ with the subse-

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§ The ore reserve of alumstone at Pingyang, Chekiang, was formerly estimated by Yih of Academia Sinica and recently reestimated by Chern of The National Geological Survey of China. Chern's figures are as follows: Rich ore 235,723,750 tons and poor ore at 317,028,074 tons. Assuming the percentage of alunite present in the alumstone to be 60 and 30 for the good and poor ore respectively, a total production of alum of 174 million tons is possible and from which about 10 million tons of aluminum and 18 million tons of potassium oxide can be theorectically extracted. Another deposit of alumstone at Luchiang, Anhwei is recently estiamted by Cheng and Chern of the Survey to be about one tenth of the Pingyang deposit. Yih's report is published in Memoir No. XI of the National Research Institute of Geology of Academia Sinica while the reports on Luchiang Alunite to be referred to Mem. Geol. Surv. China, Ser. A, No. 13, pp. 154-162, 1935, and in this bulletin.

quent production of both pure Al_2O_3 and K_2SO_4 is a promising field for investigation.

II. PREVIOUS INVESTIGATION

Cameron[1] patented a process for decomposing alum at 750°C. while Tilley[2] prefered the temperatures ranging from 800-1000°C. Burnt Alum is prepared by Hirota[3] in a similar manner. The elimination of water of crystallization is investigated by Hertwig[4] who pointed out that at 100°C. about 10 mols of water in the alum can be driven off and at 120°C., even for 12 hours, 5 mols of water are still remaining. The last traces of water are always present and difficult to drive away even the temperature is raised to 280°C. The present paper presents the behavior of alum at elevated temperatures leading toward its thermal decomposition to alumina, K_2SO_4 and SO_3.

III. SOURCE OF MATERIAL

Potash alum obtained on the market is usually contaminated with impurities. Recrystallization is therefore necessary to secure a pure sample. It is to be noted that pure alum should be used in industrial scale as well for the production of pure alumina. The employment of recrystallized alum for present study is not at all for theorectical viewpoint, but it is proposed to use pure alum wherein impurities can be entirely eliminated and to ensure the production of pure alumina in commercial scale. To purify alum at a starting point will be much easier than in later stages. The analysis of the purified alum is shown in Table I.

Table I. Composition of Purified Alum

Constituents	Al_2O_3	K_2O	SO_3	H_2O	Summation
Analysed Value	10.60%	10.05%	33.70%	45.59%	99.94%
Calculated Value	10.74%	9.93%	33.75%	45.58%	100.00%

IV. EFFECT OF TEMPERATURE ON THE EXTENT OF ALUM DECOMPOSITION

On gradual heating from 105°C to elevated temperatures up to 950°C., the alum will first evolve the water of crystallization then the decomposition of $Al_2(SO_4)_3$. The K_2SO_4 which has a much higher decomposition temperature about 950-1000°C will still remain as K_2SO_4 without any splitting up into K_2O and SO_3. In order to ascertain the degree of decomposition which can be indicated by the total loss on heating at different temperatures the following experiments are carried out:

1. Total Loss on heating and the loss of water and SO_3
2. Rate of Decomposition at different temperatures
3. Temperature and time relationship on Decomposition

EXPERIMENTAL

(1) *Total loss on heating and the Loss of water and SO_3:—*

2.5 grams of powdered alum are weighed into a 10 cc. platinum crucible and calcined in a vertical electric tube furnace at a controlled temperature from 150-950°C. The temperature interval being either 50° or 100°C. At 105°C, the determination is made in a double-jacketed oven containing a constant boiling mixture of glycerine and water. Constant weight is attained at each temperature except at 550, 600 and 650°C at which the constant weight is very tedious to attain as the increment at each weighing is considerably small. The figures given in Table II are the average of several runs.

Table II

Total Loss and the Loss of H_2O and SO_3 of Alum on Heating

Temp.	Total Loss	Loss of Water	Loss of SO_3	Time of Heating
105°C	27.77%	27.77%	0	40 hrs
150°C	44.78	44.78	0	5 "
200°C	45.21	45.21	0	5 "
300°C	45.50	45.50	0	5 "
400°C	45.59	45.59	0	5 "
500°C	45.71	45.59	0.12%	8 "
550°C	46.23	45.59	0.64*	12 "
600°C	53.01	45.59	7.42*	30 "
650°C	58.69	45.59	13.10*	10 "
700°C	70.47	45.59	24.88	18 "
750°C	70.48	45.59	24.89	7 "
800°C	70.48	45.59	24.89	3.5"
900°C	70.50	45.59	24.91	3 "
950°C	70.79	45.59	25.20	2 "

*Constant weight is not attained at these temperatures

It is quite evident that the water of crystallization is very difficult to drive away and it is quite impossible at 105°C which is commonly employed to determine this water. The fusibility of alum at low temperatures is responsible for this phenomenon because the alum powder melts to a fused mass and thus inhibits the evolution of water freely to the surrounding air. Between 550-650°C SO_3 starts to evolve at very slow rate. If the heating at this temperature is prolonged considerably, it is quite probable that all the $Al_2(SO_4)_3$, at least a large part, can be decomposed. From 750°C. and on, the evolution of SO_3 becomes much faster and at 950°C a slight decomposition of K_2SO_4 is indicated by the slight loss of SO_3 that by calculation should belong to the potassium salt.

Since the estimation by difference is more or less unreliable, direct determination of the SO_3 remaining in the alum after calcination will be served as a check. SO_3 is not expected to set free at temperatures below 300°C, consequently calcined samples above 300°C are only required for analysis. Table III gives the data showing the SO_3 remaining in the original sample. The theorectical values given in the table III serve the purpose for comparison.

Table III. Direct Determination of SO_3 Remaining

Temperature	SO_3 Remaining		Theorectical Value	Loss of SO_3
300°C	60.30%		62.02%	1.72%*
400	61.95	Anhydrous Alum	62.02	0.07
500	61.52	$Al_2(SO_4)_3.K_2SO_4$	62.02	0.50
550	61.07	as basis	62.02	0.95
600	——		——	——
700	29.10		28.99	-0.11
750	29.11	Decomposed Alum	28.99	-0.12
800	29.10	$Al_2O_3.K_2SO_4$	28.99	-0.11
850	29.05	as basis	28.99	-0.06
900	29.04		28.99	-0.05
950	28.47		28.99	0.52**

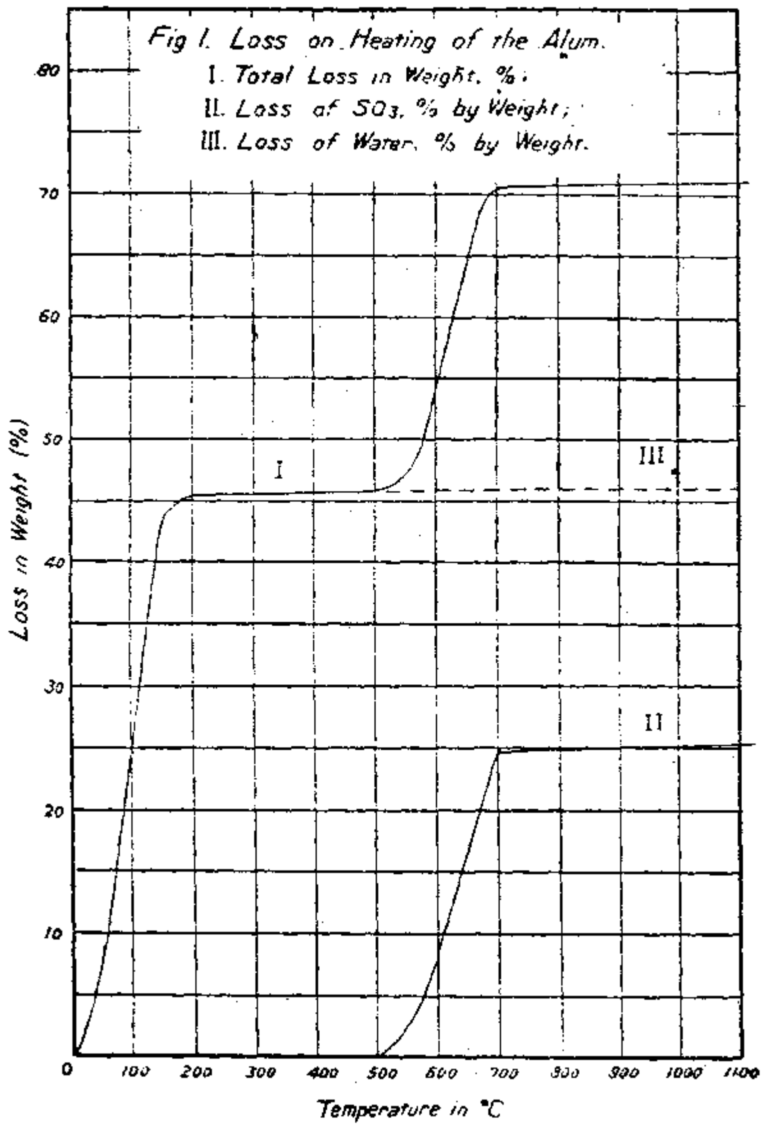
*Last traces of water are still remaining.

**This definitely indicates that potassium sulphate begins to decompose at 950°C.

Fig. 1. Represents the graphical presentation of the experimental results of Tables II and III.

(2) *Rate of Decomposition at different temperatures:*

2.5 grams of the powdered alum are calcined at different required temperatures. The interval being either 50° or 100°C. The calcined mass is weighed periodically (at either quarter, half, full or several hours depends upon the conditions) weighed until a constant weight is attained. The experimental data occupies considerable space therefore a graph showing the rate of decomposition of alum is more instructive and clear (Fig. 2). The duration of heating is sometimes extended to 30 or 40 hours but most of the experiments are carried out under 20 hours. The maximum hours of heating on the X-axis of the graph is limited only to 18 hours.



(3) *Temperature and Time Relationship on Decomposition:*

From Fig. 1 and Table II and III, it is evident that the sulphur trioxide begins to evolve at 550 C, but at this temperature the rate of evolution is so slow that a constant weight cannot be attained even after a prolonged heating up to 30 hours. However, the rate increases remarkably at 700 C, at which, a constant weight can be reached within 15 hours. To determine this relationship samples of 2.5 grams heated at temperatures ranging from 700-950 in 50

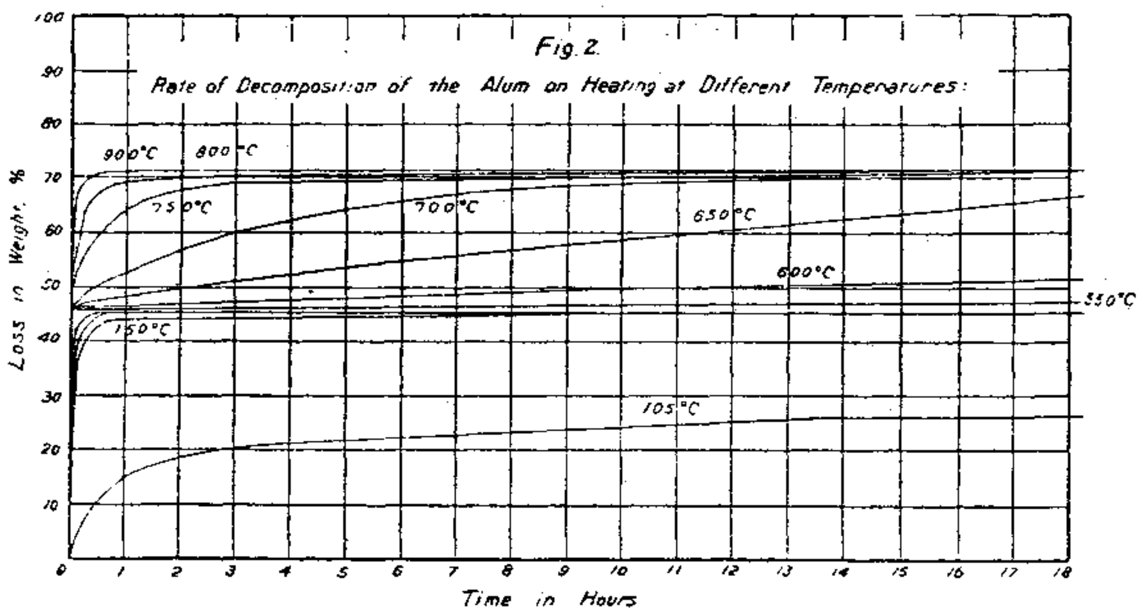


Fig. 2. Rate of Decomposition of the Alum on Heating at Different Temperatures:

intervals are carefully investigated. The experimental data are given in Table IV and Fig. 3.

Table IV. Temperature—Time Relationship

Temperatures °C	700	750	800	850	900	950
Time duration in hours	15	2.5	2.5	1	1/2	1/4

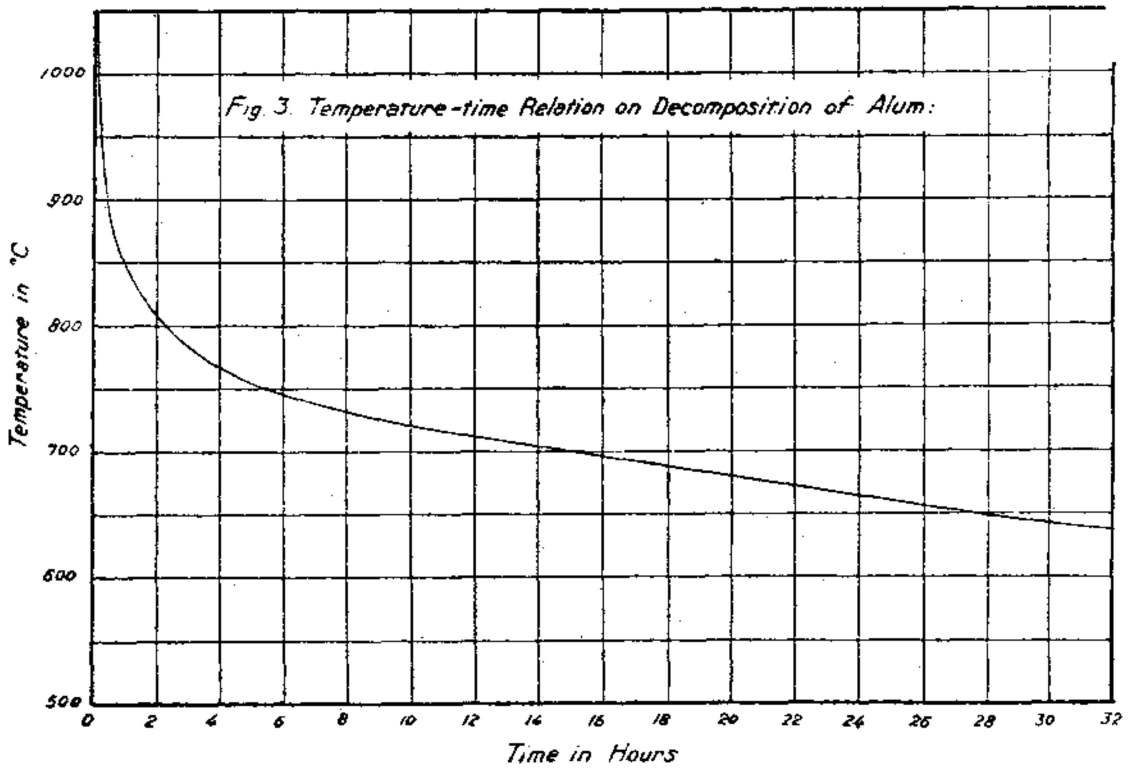


Fig. 3. Temperature-time Relation on Decomposition of Alum:

V. PRODUCTS OBTAINABLE FROM THE THERMALLY DECOMPOSED ALUM

It is definitely shown in the above that the alum under the conditions mentioned is possible to produce calcined alumina and water soluble potassium sulphate. In order to show the purity of products obtained, analytical examination is further carried out to acertain their constituents.

EXPERIMENTAL

(1) *Purity of Alumina*: about 0.10 gram of the sample is fused with potassium pyrosulphate in a quartz crucible. When fusion is complete the mass is dissolved in hot water and filtered if necessary. Large amount than 0.10 gram will yeild voluminous precipatate of colloidal nature which is very troublesome in subsequent filtering and washing. From the filtrate aluminum is precipatated as hydroxide. Redissolving and reprecipatation is considered not necessary in this case. The aluminum hydroxide is then ignited and finally weighed as aluminum oxide.

Table V. Purity of Alumina

	1	2	3	Average
Weight of sample taken	0.1000	0.1000	0.1000	0.10gr.
Purity of Alumina in%	99.69%	99.82%	99.74%	99.75%

(2) *Purity of Potassium Sulphate Recovered*: Potassium sulphate is recovered from the water extract of the calcined alum by crystallization. The carefully dried salt is analysed for potassium and sulphur trioxide in the usual analytical procedure.

Table VI. Purity of Potassium Sulphate

	SO_3	K_2O	Total
K_2SO_4 Crystallized	45.70%	53.90%	99.48%
K_2SO_4 Recrystallized	45.85%	53.95%	99.80%
Theorectically	45.94%	54.06%	100.00%

VI. DISCUSSION

In view of the enormous deposit of alumstone occurring in China and scarcity of bauxite so far known, it is of great importance to investigate the alumstone as the raw material of aluminum resources rather than potash. Among the many methods[6] existing for the winning of aluminum oxide or alumina from alumstone, the thermal decomposition of alum extracted from alunite seems to be the best and easiest process and probably the most economical one as well. It involves merely heating the alumstone to a certain degree that the subsequent extraction with sulphuric acid§ to produce alum is possible. The yield of alum can be increased by the addition of potassium sulphate as indicated by a previous experiment. It is therefore with proper control in the heating and extraction, the maximum yield of pure alum will be much higher than the generally expected value of 174 million tons from Pingyang deposit alone. When working from alum to alumina, the purified alum from the start is much desired and thus insures a pure product at the final state. Since the process is so simple, the initial investment will undoubtedly be low. The other known method of importance is the ammonia method. This not only creates trouble in precipatation, and the washing and filtering of colloidal aluminum hydroxide, but requires also ammonia which is not yet produced in China and the investment to produce such a product is very expensive. The formation of a mixture of potassium and ammonium sulphate gives probably the use of fertilizer only while the pure potassium sulphate from thermal decomposition can be employed for various purposes. Many other methods have either been patented or proposed, but all of them requires very high temperature other than 900°C or the employment of other chemicals and complicated processes.

Considering from various angles to solve this problem industrially, the process of thermal decomposition is without doubt the best solution. It employs a low temperature of about 850°C for both the thermal decomposition of alumstone and alum, needs very cheap chemical that is sulphuric acid alone (the potassium sulphate is produced in the process) and requires very simple apparatus such as muffle furnaces and settling, extraction and crystallization pans which can be made of wood.

However, the abnormal property of expansions during calcination must be carefully investigated. A study in a more enlarged scale of experimentation to ascertain its possible elimination, is deemed necessary. This is chiefly due to the considerable quantity of water of crystallization, and its low fusion point so the mass will expand to several times its original volume. This defect can be solved by crushing the fused mass at about 600°C before subjecting to 850°C.

VII. SUMMARY

Potash alum is subjected to thermal decomposition from 105 to 950°C at intervals of either 50 or 100°C. The water of crystallization can be quantitatively

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§ Recent communication with Prof. Tsai of Yenching University that the effect of extraction with higher concentration of sulphuric acid up to 25% will be increased.

expelled at 300-500°C. and 400°C seems to be the most favorable and safeworking condition. Sulphur trioxide liberates at 550°C but 850°C. is the most convenient and efficient temperature to decompose alum. The products obtained are quite pure: Alumina 99.75% and Potassium sulphate 99.80%. A discussion is given as to probability of the thermal decomposition process as applied industrially since it involves the simplest in the working procedures as compared to the other processes known so far.

Acknowledgement:—The authors are indebted to Prof. C. H. Kao of Tsing Hua University for his valuable suggestions on analytical procedure.

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THE CASSITERITE-ARSENOPYRITE PIPES IN SOUTHERN HUNAN, CHINA

BY C. C. WANG & Y. H. HSIUNG

CONTENTS

I. INTRODUCTION

The cassiterite-arsenopyrite deposits described in this paper are all situated along the Chungshui, a main tributary of the Siang River; they are located at some 160 li south of Hengyang or 660 li from Changsha, the capital of Hunan. Politically these deposits belong to Changning and Kweiyang districts. Though they have been mined long ago, no systematic study has yet been made except a preliminary report[1] published by the Geological Survey of Hunan. The writers visited the

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[1] C. C. Tien: Reports on the tin & arsenic deposits of Tanshanwo, Taishunlung and Hsianghualing, Hunan". Bull. Geol. Surv. Hunan, No. 11, 1931.

deposits during 1932 and had the privilege of making, for the first time, a detailed microscopic examination of the ores and rocks. The detailed description of the mining and metallurgical treatment of the ore is given in the Chinese text.

II. PHYSIOGRAPHY

Going southward from the city of Hengyang for some 130 li to the village of Hengtou, which is about 25 li from the cassiterite-arsenopyrite deposits, we found on the way numerous low ridges and isolated hills from several tens to hundred metres high above the valleys. Between these ridges there often occurs a flat farming country sometimes 4 or 5 li in width. All these features seem to indicate a topography of advanced maturity. But from Hengtou southwestward to the mining district, there rises a bold range with steep slopes about 200-350 metres in height above the plain. On arriving at the summit of the range a strange feature is met with, for the summit itself is again a gentle rolling country representing an erosion surface of late maturity (Pl. II, figs. 1, 2). Hence, from Hengyang to the tin and arsenic mines the physiographic development as shown on the route may be distinguished into two stages: 1. Remains of an old advanced mature surface about 200-400 m. high above the Chungshui river. Its erosion seems to have been completed before Eocene. 2. The region was then uplifted and river erosion rejuvenated by which a new level also marked by mature surface was finally reached. The beginning of this second erosion cycle was probably during middle or late Tertiary, possibly after the deposition of the Eocene sandstone and shales. Consequently, the Eocene beds is bevelled by the new mature surface. The old mature land in the vicinity of the mines is mainly constituted of Carboniferous limestone, in which sink holes and underground streams abounds, often forming a curious drainage system.

III. GENERAL GEOLOGY

The geological formations in the vicinity of the Peichenglung mine as recognised by Mr. C. C. Tien, Geologist of the Hunan Geological Survey, are given in ascending order as below:—

1.	Hsikuanshan limestone.........	Upper Devonian
2.	Wanloshan limestone	Carboniferous
3.	Tseishui sandstone	

As to the geological structure Mr. Tien considered that the Hsikuanshan limestone formed a syncline between Peichenglung and Fengmuchiang and an

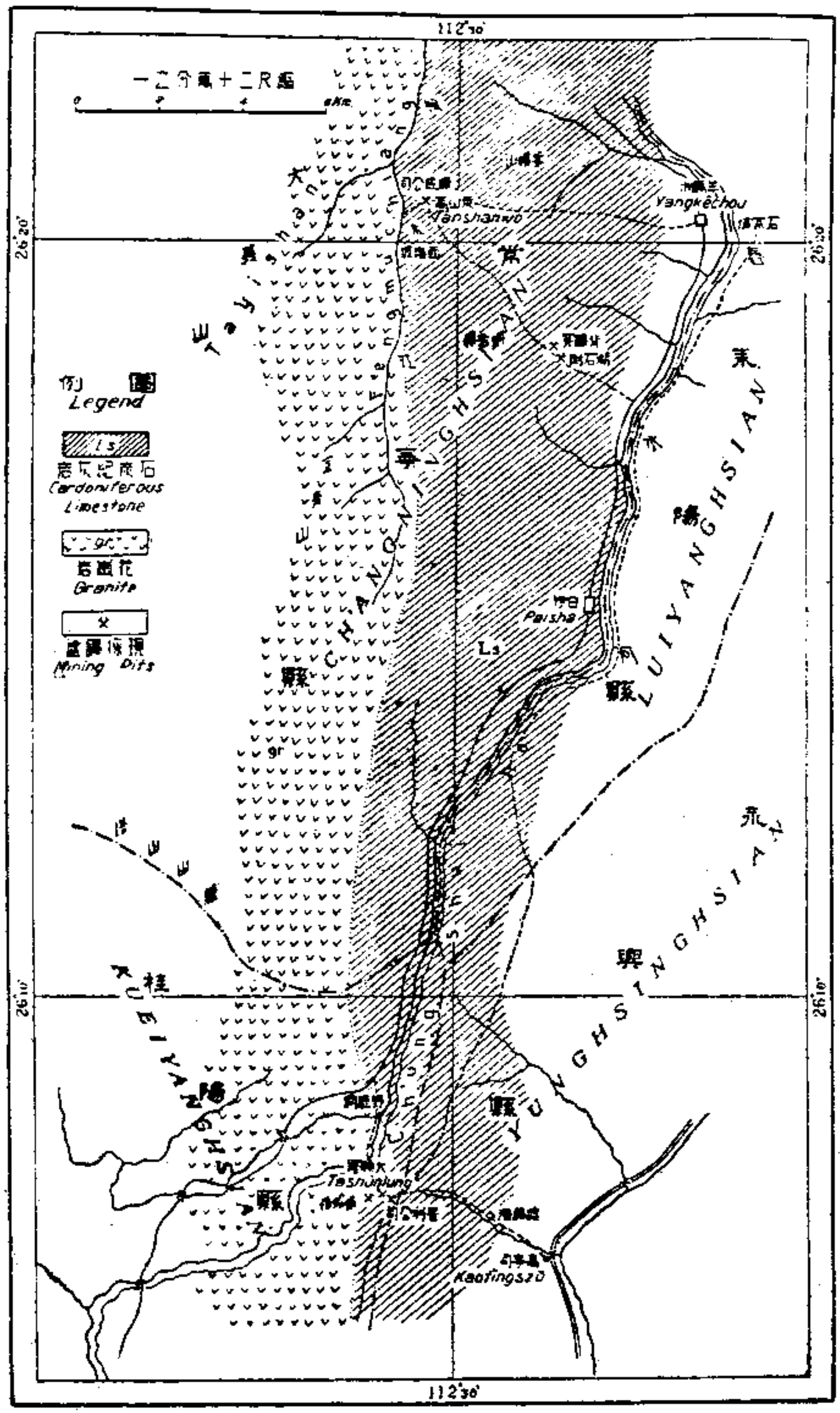


Fig. 1. Generalized geological map of the Changning and Kueiyang cassiterite-arsenopyrite deposits, Hunan.

anticline between the former and Tanshanwo, making the Wanloshan limestone and Tseishui sandstone successively exposed along the east limb of the anticline. From the writers' observation, however, the syncline between Peichenglung and Fengmuchiang seems to be situated farther west than that shown in Mr. Tien's map and is mainly constituted of white sandstone and black shale (Fig. 2) probably belonging to the Tseishui series. Its underlying limestone is, thus, most probably the Wanloshan formation. It seems that in the vicinity of Peichenglung there is really no Hsikuanshan limestone, all belong to the Wanloshan formation. The latter often contains numerous flint nodules arranged parallel to the bedding plane and is fossiliferous with corals and brachiapods usually exposed on its weathered surface. It is extensively exposed southward to Chuanyenpei and Taoshihhu and profoundly metamorphosed into marble at its contact with granite along the Fengmuchiang stream. The Tseishui series, though widely distributed on the west of Peichenglung, is largely covered by alluvium, only a little sandstone and shale can be seen.

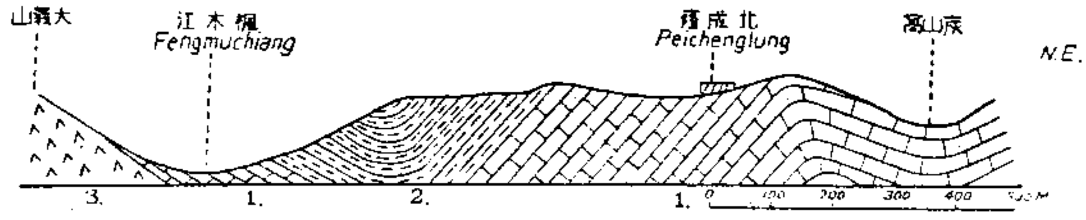


Fig. 2 Geological section from Peichenglung to the Fengmuchiang Scale 1:10000

1. Carboniferous limestone
2. Carboniferous sandstone & shale
3. Granite

50 li south from Peichenglung is the Tashunlung mine where Mr. Tien recognised two Carboniferous formations, the Wanloshan limestone and the Tzemenchiao series, the contact of which was supposed to be an overthrust. The writers are, however, unable to realize such an overthrust and prefer to include all the formations under the Tzemenchiao series.

Owing to the intense metamorphism and complicated structure at Peichenglung and Tashunglung any detailed classification of the rock formations seems to be extremely difficult, unless by exceptionally careful study. Such names as Wanloshan limestone, Tzeishui series and Tzemenchiao limestone etc. are, therefore, not adopted in this paper, all formations being grouped together under the general name of Carboniferous system. The geological features are much similar to the tin deposits of Malay Peninsula, the world famous tin-producing centre, where the ores are also mostly found in Permo-Carboniferous limestone.

IV. PETROGRAPHY

THE GRANITE OF FENGMUCHIANG

Granite is abundantly exposed along the Fengmuchiang stream, west of Peichenglung.

Megascopic characters. Two types of granite may be distinguished; one is even and fine-grained and the other is rather coarse. In the latter the felspar crystals are sometimes 2 cm. long with well development of cleavage faces, the larger grains of quartz being commonly 1 cm. in diameter. The color of felspars is white. Biotite often finer than both felspar and quartz is also easily recognised in the hand-specimens. The latter two minerals make up the greater part of the granite while the former one is only sparsely distributed.

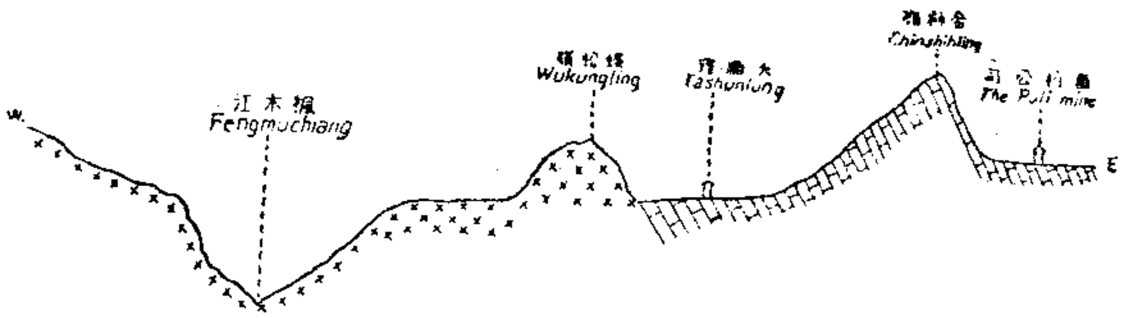


Fig. 3. A section from the Puli mine to the Fengmuchiang stream, showing the topographic feature of an old advanced maturity.

Microscopic characters. Under microscope the felspars are composed of both potash- and soda-varieties and usually profoundly altered to kaolin and to minute flakes of mica. The potash variety is orthoclase sometimes in distinct Carlsbad wins. The soda felspar occurs nearly in equal amount as the orthoclase or still more. Its repeated-twin lines are often visible when it is fresh. It probably belongs to albite with its medium index (Nm) about 1.53. Its differentiation from orthoclase will be more difficult when its twinning appearance is lost due to deep alteration. The mean index of the latter is, however, about 1.525 and is therefore much lower than that of the former.

Mr. C. C. Tien found some granite containing a notable amount of arsenopyrite, cassiterite, pyrite and chalcopyrite at Tsaochiachung, west of the Fengmuchiang-

THE GRANITE OF WUKUNGLING (Pl. II, Fig. 3)

Megascopic character: Though this rock belongs to the same intrusion as the Fengmuchiang granite, its porphyritic texture is more prominant with two generations of felspar, the fine grained one and the phenocrysts, the latter is 2-4 cm. in length. Biotite is much more abundant than in the Fengmuchiang granite, but quartz is less.

Microscopic character: The decomposition of the felspar gives rise to much kaolin and a little sericite. Orthoclase seems more plentiful than albite. Biotite is sometimes altered to chlorite. One remarkable feature is the presence of fluorite which occurs in great amount and exhibits very low negative relief under microscope.

In comparison with the Fengmuchiang granite it is obvious that in the present rock, biotite is more abundant with a greater amount of orthoclase and fluorite while quartz is only sparsely represented.

The granites from Wukungling and Fengmuchiang have been analysed by the junior author and their compositions are as follows:

	Fengmuchiang granite		Wukungling granite	
	Per Cent	Mol. prop.	Per cent	Mol. prop.
SiO_2	75.51	1.258	71.71	1.195
TiO_2	0.07	0.001	0.03	0
Al_2O_3	13.32	0.130	13.12	0.128
Fe_2O_3	0.16	0.001	0.22	0.0014
FeO	1.29	0.018	2.60	0.036
MnO	0.02	0	0.50	0
MgO	0.02	0	0.18	0.0045
CaO	0.61	0.011	1.63	0.029
Na_2O	5.16	0.083	5.20	0.084
K_2O	4.22	0.045	5.68	0.060
P_2O	0.06	0	0.09	0.001
H_2O	0.40	0.021	0.41	0.022
F			0.02	0.001
S	0.02	0	0.06	0.002
	100.86		100.975	

The standard mineral compositions of the norms calculated from the above table are as below:—

	Fengmuchiang granite	Wukungling granite
	Per cent	Per cent
Quartz	27.66	20.60
Orthoclase	25.02	33.36
Albite	43.492	35.63
Anorthite	0.556	
Acmite		0.46
Na_2O SiO_2 (in pyroxene)		1.83
Diopside	2.228	5.99
Hyperthene	0.92	1.78
Fluorite		0.07
Pyrite		0.12
Magnetite	0.23	
Apatite		0.34
Ilmenite	0.15	
	100.256	100.28

The magma characters as inferred from the norms are:—

	Class 1	Order 4	Range 1	Subrange 3
	$\left(\frac{\text{Sal.}}{\text{Fem.}} > \frac{7}{1}\right)$	$\left(\frac{Q}{F} < \frac{3}{5} > \frac{1}{7}\right)$	$\left(\frac{K_2O' \text{-} Na_2O'}{CaO'} > \frac{7}{1}\right)$	$\left(\frac{K_2O'}{Na_2O'} < \frac{5}{3} > \frac{3}{5}\right)$
Fengmuchiang granite	$\frac{96.782}{3.492} > \frac{7}{1}$	$\frac{37.66}{69.068} < \frac{3}{5} > \frac{1}{7}$	$\frac{9.38}{0.11} > \frac{7}{1}$	$\frac{4.22}{5.16} < \frac{5}{3} > \frac{3}{5}$
Wukungling granite	$\frac{89.69}{10.59} > \frac{7}{1}$	$\frac{20.70}{68.99} < \frac{3}{5} > \frac{1}{7}$	$\frac{X}{O} > \frac{7}{1}$	$\frac{5.68}{4.20} < \frac{5}{3} > \frac{3}{5}$
	Persalane	Britannare	Liparase	Liparose

It is evident that the Fengmuchiang and Wukungling granites belong not only to the same class and to the same order but also to the same subrange liparose in magmatic divisions.

DOLOMITIC MARBLE

In the vicinity of Peichenglung and Tashunlung mines the Carboniferous limestone has mostly been transformed into a dolomitic marble which often exhibits curiously weathered appearance and is usually used, by the natives, as a guide to prospecting. In fact, important tin and arsenic deposits show nearly in every case intimate relation with dolomitization. From a microscopic examination of the ores and rocks it is concluded that the dolomite is commonly replaced by ore and silicate minerals. The process of dolomitization seems, therefore, to have taken place prior to the introduction of the ore solution in the Carboniferous limestone. As dolomite is particularly susceptible to ore solutions, the ore bodies are, thus, often deposited in the dolomite marble.

The analyses of the dolomite and calcite marbles from the Peichenglung mine by the chemical laboratory of the Geological Survey are given below:—

	Dolomite marble		Calcite marble
	(1)	(2)	
Insoluble matter	0.45	0.66	0.54
R_2O_3	0.16	0.36	
CaO	31.25	31.06	50.82
MgO	21.03	21.58	4.27
Co_2	47.23	46.30	44.09

Note: 50% of the insoluble matter is SiO_2, the rest being Fe_2O_3 and others.

V. THE ORE DEPOSITS

FORM OF THE ORE BODIES

The cassiterite-arsenopyrite deposits are all in the form of pipes and are located in the metamorphosed limestone near its contact with the Fengmuchiang and Wukungling granite intrusion. The important mines consist of Peichenglung, Chuanyenpei, Taoshihhu, Tashunlung and Puli etc.

In the Peichenglung mine which is worked for both cassiterite and arsenopyrite, the main ore body is not in a typical pipe form but elliptical or rectangular in cross section. The minor axis ranges from 1 to 3 ft. and the major one from 1 to 20 ft. When the ore body swells, special ore shoots often occur. The pipe is generally inclined from southwest to northeast and connected with two branches both circular in cross section, but only one foot or four inches in diameter. South of the main pipe there is a small one the cross section of which is also elliptical and its minor axis is only three inches and major axis five inches. Its upper portion as mined before is, however, reported to have been 5 to 10 ft. in dimensions. Besides, there is a sphalerite vein in the neighborhood of the main pipe, but as it has been abandoned long ago its detailed form is not known.

Eight li southeastward from Peichenglung is the Chuanyenpei mine working only for arsenopyrite. The ore body has a roughly circular cross-section with varying diameters of 5 inches to 1 ft. But in its upper portion a swelled ore shoot 10 ft. in diameter was met with.

The Taoshihhu cassiterite-arsenopyrite mine situated two li southeast from Chuanyenpei, was abandoned long ago, but judging from the space left in the shaft the ore body seems to be in an irregularly elliptical cross-section with axes at some ten ft. 30 li south from Taoshihhu there is a third cassiterite-arsenopyrite mine called Tashunlung. The ore body inclined to north by east is also elliptical in cross-section. Two swelled ore shoots were mined before, one from 10 to 20 ft. in transversal dimensions and the other from 7 to 10. The lower portion of the ore body is divided into three branches, all elliptical in cross-section. One is from 6 inches to 2 ft. in transverse axes, the second from 1 to 3 ft. and the third from 8 inches to 3 ft.

The Puli arsenopyrite mine is about three li east from Tashunlung. The cross-section of the ore body is elliptical at one and three ft. in dimensions. There is a branch whose cross-section is circular at about 1 ft. in diameter.

Near the Puli mine there occurs, in addition, a sphalerite vein about one foot in width and in the vicinity of Tashunlung some hematite bodies containing scattered cassiterite grains, the latter are also worked by the miners.

In conclusion we may say that the cross-section of the main ore bodies is usually elliptical, that of the branches, if any, being commonly circular (Pl. IV, figs. 1, 2, Pl. VI, fig. 2, & Pl. VII, fig. 1). They are all frequently crooked and sometimes expanded or reduced in transversal dimensions. The known depth of the ore body as mined in Peichenglung is more than one hundred metres without notable diminution both in volume and in quality, but the enlarged ore shoots seem to be often at shallow depths.

MINERALOGY

THE ORE MINERALS

1. From the Peichenglung pipe

The Peichenglung pipe is composed chiefly of arsenopyrite, cassiterite and chalcopyrite, which make about 90% of the total. The arsenopyrite alone amount to about 50% of the whole. The three minerals usually constitute banded (Pl. V, Fig. 1) or orbicular structure with outermost zone of arsenopyrite and central zone of chalcopyrite. Such structure probably results from rhythmic deposition and metasomatism of the country rock. Besides the three principal minerals, there are some stannite, bornite, sphalerite, enargite, and tennantite; these minerals except bornite can only be recognised under microscope.

Arsenopyrite: Examination of the hand specimens shows that arsenopyrite occurs both in fine-grained masses and in individual idiomorphic crystals. The latter are prismatic often 4 or 5 mm in length and scattered in other ore or gangue minerals. The massive arsenopyrite may be sometimes up to several ten catties in weight. Under microscope, however, the fine-grained masses show also distinct crystal outline with rhombic sections especially common.

The arsenopyrite is the earliest ore mineral formed, and frequently it shows ragged outline (Pl. VII, fig. 3) when in contact with cassiterite and chalcopyrite, suggesting its replacement by the others.

Cassiterite: The grains of cassiterite are usually so fine that they can not be distinguished from one another unless examined under microscope. There is only one hand-specimen in which the cassiterite crystals are well developed at about 3 to 4 mm. in dimensions. The color is commonly brown and rarely black brown, and under microscope it shows sometimes irregular zonal distribution (Pl. XI, fig. 1). Cracks are abundant and prismatic cleavages are often distinct. In polished sections the cassiterite generally shows a bad polish and often occurs as residual grains enclosed in stannite or chalcopyrite, indicating that their deposition is later than cassiterite. The latter occurs frequently in broad bands alternating with arsenopyrite and chalcopyrite. Though cassiterite is much less in amount than arsenopyrite, it attracts the special attention of the miners, because the price of tin is much higher than arsenic.

Pyrite: Pyrite occurs only in small quantity and its genetic relation with both arsenopyrite and cassiterite is not clear, as no mutual contact among them is observed. It is, however, certainly earlier than chalcopyrite and is usually replaced by the latter.

Chalcopyrite: It generally occurs in massive form without crystal outline and shows under microscope a weak anisotropism and sometime repeated twinning under crossed nicols. Its deposition may be distinguished into three epoches but the first epoch is more important than the other two. In the chalcopyrite of the first generation, there occur sometimes sphalerite veinlets or gashes, or the latter mineral includes the residual grains of the former, all suggesting that chalcopyrite is replaced by sphalerite. More commonly is the occurrence of numerous stannite veinlets or gashes in the chalcopyrite (Pl. VIII, fig. 2), usually arranged along certain directions. This is much like graphic intergrowth of contemporaneous deposition, although it is believed that replacement of chalcopyrite by stannite is a more probable explanation. The process of replacement seems to have started at various points in the chalcopyrite during the same time. Larger gashes of stannite are also sometimes surrounded by chalcopyrite, constituting centrifugal replacement (Pl. VIII, Fig. 1).

Certain larger stannite sections frequently contain along their cleavage planes blades of chalcopyrite suggesting probably an exolution texture of grating type (Pl. VIII, fig. 3). In this case the deposition of chalcopyrite must be simultaneous with that of stannite and is therefore later than the chalcopyrite of the first generation; in other word, it constitutes the second stage chalcopyrite.

Some chalcopyrite gashes (Pl. IX, fig. 1) or blades are also contained in bornite commonly near the cracks (Pl. VIII, Fig. 4) of the latter mineral, a feature suggesting replacement of bornite by chalcopyrite. If this is the case, this chalcopyrite here must be the latest one formed; it is the chalcopyrite of the third generation.

In conclusion we may say that the deposition of chalcopyrite is divided into three periods which are occasionally overlapping; its main load was however precipitated during the first period.

Sphalerite: Generally in massive form and is only found in a few hand-specimens. It is easily distinguished under the microscope from stannite by its gray color, isotropic character, and yellow brown powder, and usually replaced by the veinlets and gashes of the latter (Pl. VII, Fig. 4).

Stannite: It is massive and shows intimate association with chalcopyrite as previously mentioned. In the case of exsolution texture (Pl. VIII, fig. 3) the included blades of chalcopyrite are generally arranged in three directions, two intersecting at right angle probably along the cubic cleavages of the stannite, and the third one obliquely cutting the preceding two along its twinning lines.

Enargite: This mineral shows under the microscope a strong anisotropism of greenish blue and copper pink. Repeated twinning lines are sometimes visible. Aggregates of anhedral grains common. The contacts between enargite and bornite usually show mutual boundary, but the latter also occurs along the contact between enargite and arsenopyrite, indicating that bornite replaces enargite, the contact zone being taken for conducting solution.

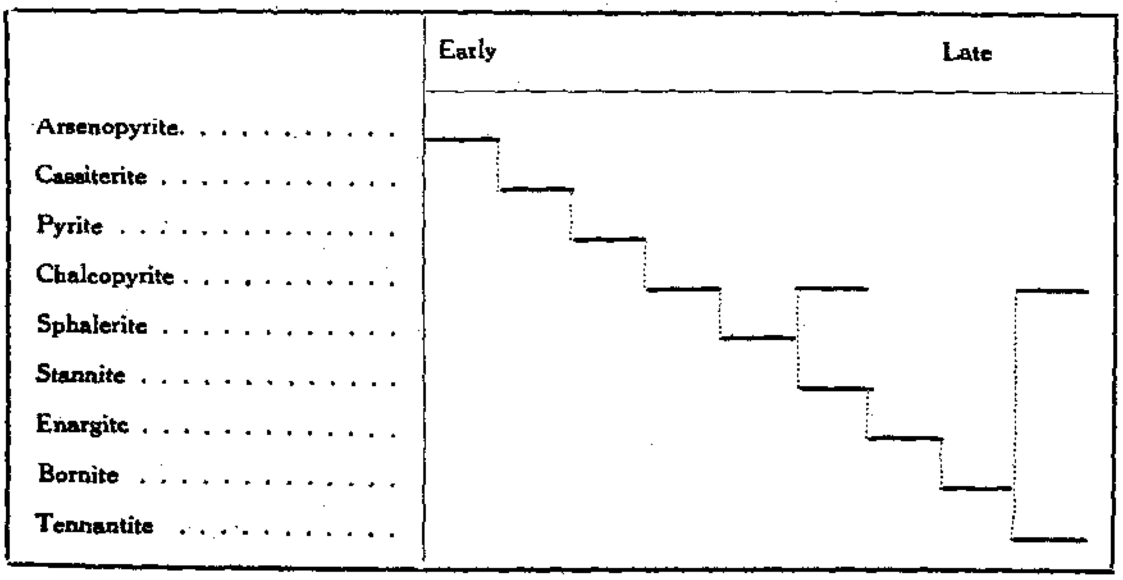
Tennanite: In grayish white color. Isotropic under crossed nicols. Negative to all reagents as suggested by C. M. Farnham except HNO_3 fume. Sometimes found along the contact between enargite and bornite, which may indicate tennantite later than enargite or even later than bornite.

Bornite: Generally occurring in massive form or as veinlets and gashes in chalcopyrite (Pl. VIII, fig. 4). Easily recognised in hand specimens by its tarnished purple to greenish blue color. It replaces chalcopyrite of the second generation and is itself replaced by the same mineral of the third generation.

If the above mentioned ore minerals are arranged in the order of abundance, we have (1) arsenopyrite (most abundant) (2) chalcopyrite (3) cassiterite (4) stannite (5) bornite (6) sphalerite (7) enargite (8) tennantite (9) pyrite. But the order of deposition is as follows:—

Table I.

The paragenesis of the ore minerals from the Peichenglung mine.



2. *From the Liutzelung hypothermal sphalerite vein*

About one li southeast from the Peichenglung mine is the abandoned Liutzelung sphalerite vein. Some specimens collected by the writers from an old shaft show the following ore minerals under the microscope:

Arsenopyrite: It is also the earliest mineral in the ore, but only sparingly disseminated in the vein or country rock.

Pyrrhotite: It is massive and shows a strong anisotropism of creamy and reddish brown under crossed nicols. Often traversed with numerous cracks, which have partly filled with pyrite or truncated by sphalerite. The pyrrhotite is, thus, earlier than both pyrite and sphalerite. The cracks are probably due to contraction and may indicate deposition under colloidal state. It also occurs, however, as dots in sphalerite in unmixing texture and is, therefore, overlapping with the latter. Occasionally arsenopyrite residual grains are included in pyrrhotite due to the replacement of the former by the latter. Sometimes the latter replaces the former from centre outward, establishing the centrifugal replacement.

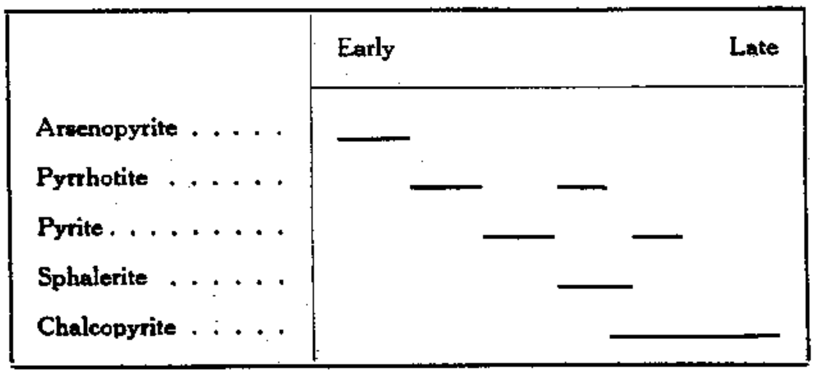
Pyrite: It is later than pyrrhotite which sometimes includes pyrite veinlets. It is partly earlier and partly later than sphalerite for both residual grains and veinlets of pyrite occur in the latter. Its deposition seems to be long and repeated.

Sphalerite: This is the most abundant mineral in the ore. It commonly contains numerous dots and rods of pyrrhotite and chalcopyrite, constituting exolution texture. Such dots and rods usually have a great tendency to be arranged in parallel directions probably following cleavage or twinning line of sphalerite.

Chalcopyrite: It is massive and mainly later than sphalerite, but may be partly overlapping with the latter as mentioned before.

The order of the Liutzelung ore minerals arranged in abundance is (1) sphalerite (2) pyrite (3) pyrrhotite (4) arsenopyrite (5) chalcopyrite, and their succession in deposition is shown below:—

Table II.



3. *From the Chuanyenpei pipe*

The ore minerals consist of arsenopyrite, chalcopyrite, tennantite, sphalerite, and pyrite, but all occur in small quantity only except arsenopyrite which is the sole mineral mined.

Arsenopyrite: This makes about 80% of the total ore minerals and generally occurs in aggregated masses of fine crystals associated with a little gangue mineral. It usually shows abundant shattered fractures which have been filled in either by chalcopyrite or by gangue minerals (Pl. IX, Fig. 2); they are, thus, all later than arsenopyrite.

Pyrite: It is only discovered under microscope in a few crystals commonly dissected with the veinlets of gangue minerals. Its genetic relation with arsenopyrite is not clear. Sometimes occurring as residual grains in chalcopyrite or as veinlets dissecting the latter. Its deposition is, thus, long and partly earlier and partly later than that of the chalcopyrite.

Chalcopyrite; Though scanty in most hand specimens, it may be in notable amount in certain specimens. Both chalcopyrite and pyrite seem to have been broken after their deposition and filled in afterwards with gangue minerals. During the formation of the ore, therefore, two epoches of disturbance have been registered: one is after the deposition of arsenopyrite, and the other after that of chalcopyrite and pyrite.

Sphalerite: Sphalerite only occurs in small gashes as a guest mineral in chalcopyrite. It distinctly replaces chalcopyrite and is itself replaced by tennantite.

Tennantite: It occurs as veinlets in chalcopyrite or in sphalerite and thus replaces both.

The succession of the above ore minerals is shown in the following table:—

Table III.

	Early				Late
Arsenopyrite	――				
Pyrite		――		――	
Chalcopyrite			――		
Sphalerite				――	
Tennantite					――

The order in abundance is (1) arsenopyrite (2) chalcopyrite (3) pyrite (4) sphalerite and (5) tennantite.

4. *From the Taoshihhu pipe*

As the Taoshihhu mine was abandoned, all the specimens have been collected from the wastes of the former operation and consist of the following minerals.

Arsenopyrite: Generally the arsenopyrite occurs as aggregates of crystals in rude bands and often shows on its polished surface a great many cracks, which have mostly been filled in with gangue minerals. Rhombic section of crystals is not uncommon.

Cassiterite: It is usually in crystals or fine grains in bands. Its genetic relation with arsenopyrite is indistinct, but it is earlier than pyrite as its residual grains are often included in the latter. Showing weak anisotropism under crossed nicols. Internal reflection is obscure.

Pyrite: It commonly occurs as residual grains in pyrrhotite (Pl. IX, fig. 3) or chalcopyrite and is therefore earlier than both.

Pyrrhotite: It is massive or forms islands in chalcopyrite (Pl. IX, fig. 3), indicating that it is replaced by the latter (Pl. IX, fig. 4).

Chalcopyrite: This is an abundant mineral next to arsenopyrite. Sometimes dissected by the prismatic crystals of silicate minerals (Pl. XII, figs. 2, 3) or replaced by sphalerite along its contact with pyrrhotite.

Sphalerite: It occurs only in a few gashes in chalcopyrite or pyrrhotite and can not be recognised unless under microscope.

The paragenesis of the ore minerals mentioned is (1) arsenopyrite (the earliest) (2) cassiterite (3) pyrite (4) pyrrhotite (5) chalcopyrite and (6) sphalerite. The sequence in quantity is (1) arsenopyrite (most abundant) (2) chalcopyrite (3) cassiterite (4) pyrite (5) pyrrhotite and (6) sphalerite.

The above mentioned four pipes belong to the Changning district, while the rest to be described belong to the Keiyang district.

5. *From the Tashunlung pipe*

Arsenopyrite: This constitutes the most abundant component of the ore. It generally occurs as aggregates of crystals or sometimes as residual grains in pyrite or other minerals. It is commonly fractured and filled in by pyrite and chalcopyrite. Its replacement by the latter two minerals is also not uncommonly observed.

Cassiterite: It is usually in crystals and replaces arsenopyrite, sometimes invading the latter along its cracks. As cassiterite is scarcely in contact with pyrite, their genetic relation is not clear though the former may be earlier than the latter.

Pyrite: This mineral is not present in large quantity but may abundantly accumulate in certain portions of the ore. Being often deeply replaced by other later minerals, it rarely preserves its crystal outline and sometimes occurs as residual grains in sphalerite or chalcopyrite.

Chalcopyrite: It is earlier than sphalerite and is replaced by it in most specimens, but always later than pyrite.

Sphalerite: It occurs in massive form and is easily recognised even with naked eyes. It usually contains numerous dots and rods of chalcopyrite in unmixing texture of mottled type (Pl. X, Fig. 1). Gashes of chalcopyrite of replacement origin are, however, also found in some sphalerite sections. The deposition of chalcopyrite, thus, began before the earliest sphalerite, continued in overlapping with the latter, and closed after its latest development.

Bornite: It commonly occurs as veinlets in chalcopyrite, and distinctly replaces it (Pl. X, fig. 2). On a small scale it also replaces sphalerite.

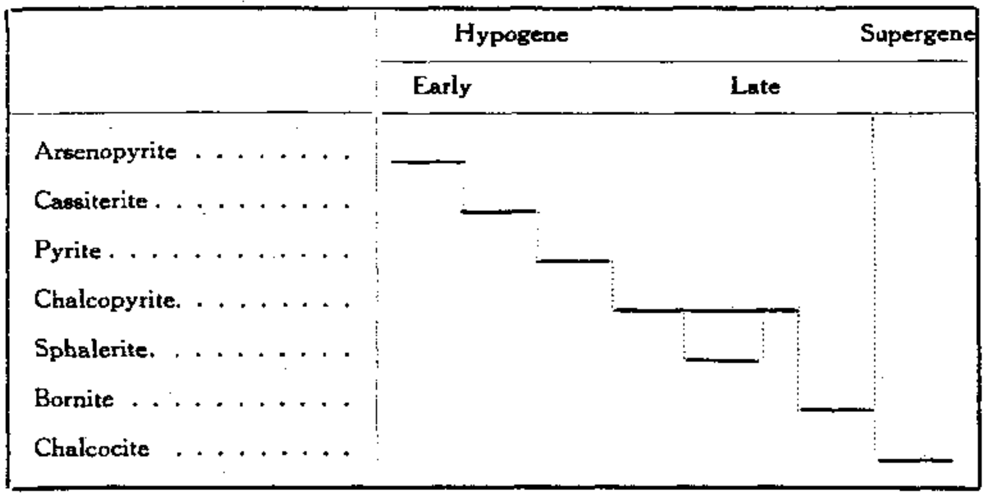
Chalcocite: It shows isotropic character in bluish white color which suggests the presence of a considerable amount of covellite in solid solution. Both HNO_3 and $FeCl_3$ give rise etching cleavages or cracks on polished surface. It usually replaces bornite and some sphalerite. The process of replacement of the former is performed either from the margin toward the centre in centripetal replacement or dissected by irregular veinlets. The chalcocite is probably of a supergene origin and occurs only in a small quantity.

If the ore minerals are arranged in abundance, the order is (1) arsenopyrite (2) chalcopyrite (3) sphalerite (4) cassiterite (5) pyrite (6) bornite (7) chalcocite.

Their succession in deposition is shown as below:—

Table IV.

The succession of the ore minerals from the Tashunlung mine



6. *From the Puli pipe*

Only arsenopyrite is known to the miners, but cassiterite is also discovered under microscope.

Arsenopyrite: It is the most abundant mineral in ore and mostly occurs in aggregates of crystals. It sometimes shows cracks filled in with pyrite (Pl. V, fig. 3) and sphalerite.

Cassiterite: It is present only in a few crystals and often replaces arsenopyrite.

Pyrite: It generally occurs as residual grains in chalcopyrite and sometimes also a few veinlets in sphalerite. Its development, thus, consists of two epoches, one covering its main deposition before the chalcopyrite, and the other after the sphalerite.

Chalcopyrite: It is massive and is distinctly replaced by sphalerite (Pl. X, Fig. 4), pyrrhotite, and stannite.

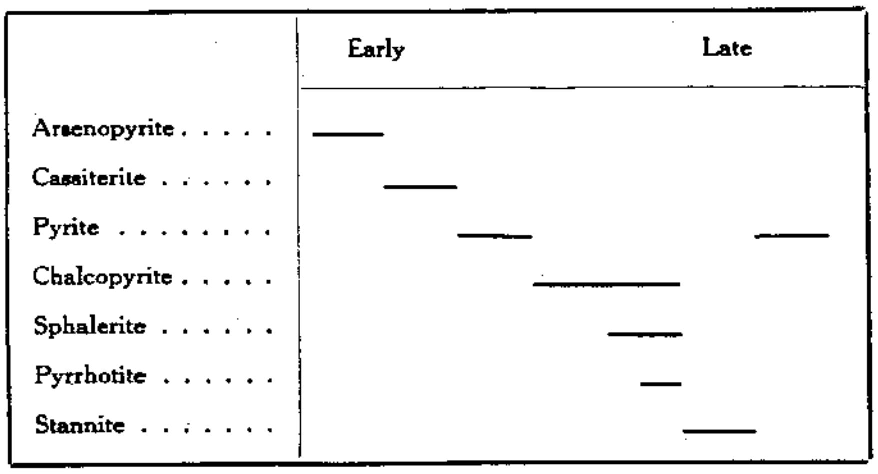
Stannite: Only occurring as a few gashes in chalcopyrite and sphalerite. It is, therefore, later than both.

Sphalerite: It is abundant in the ore and chiefly occurs as coarse crystals with distinct cleavage faces. Fine grains are, however, also present. Numerous dots and rods of chalcopyrite and pyrrhotite are generally included in the sphalerite, constituting an exsolution texture of mottled type.

The order of deposition of the ore minerals is as follows:—

Table V.

Paragenesis



7. *From the hypothermal sphalerite vein in the neigeborhood of the Puli mine*

This vein was discovered by the Puli mine during exploitation of arsenopyrite and is composed of the following minerals:

Sphalerite: It constitutes more than 90% of the total quantity of the mineral components in the vein. In hand specimens its color is black.

Pyrrhotite: It occurs as a few gashes in sphalerite and is only recognizable under microscope. It may be a little later than sphalerite though no replacement between them is observed.

Pyrite: Occurring as a few grains or veinlets in sphalerite, it is at least partly later than the sphalerite.

Chalcopyrite: It is present as a few rods in sphalerite and is apparently of later origin.

Stannite: It also occurs in a few gashes and is later than sphalerite.

8. *From the hematite bodies near the Tashunlung mine*

The form of the ore bodies is very irregular much like contact metamorphic deposits. They are composed mainly of hematite in more than 80% of the total mineral components. Besides, there are some cassiterite, pyrite and arsenopyrite.

THE GANGUE MINERALS

1. From the Peichenglung pipe

Two periods of development may be distinguished in the gangue minerals. One period was accomplished after arsenopyrite and cassiterite and closed before the deposition of chalcopyrite, while the other began after chalcopyrite. Most gangue minerals belong to the 2nd. period and only one or two species to the first. It is obvious that the silicates are usually later than the sulphides in the pipe.

Chondrodite: It occurs as tablet crystals in great amount. Multiple twinning on (001) distinct. Colorless in thin section. Nm = 1.622 ±. Interference color gives rise red of the 2nd. order (birefringence about 0.032). In a section parallel to (010) or normal to Z, $X \wedge$ twinning lamella $= 30°$. Biaxial positive property is indicated in some sections $\perp$ to one optic axis. Optic angle is large.

The mineral usually cuts the colored zones of cassiterite (Pl. XI, fig. 1) and is sometimes dissected by chalcopyrite which is occasionally developed along the cracks of the chondrodite. Some crystals of lithia mica are also developed in the chondrodite. It is, thus, later than cassiterite and earlier than both chalcopyrite and lithia mica.

Diopside: Occurring either as large radiated prismatic crystals (Pl. V, fig. 2) or as minute prisms. Color greenish gray. Hardness = 5. Nm = 1.69. (110) cleavage distinct. $Z \wedge C = 38°$. Biaxial and positive as shown in some section normal to one optic axis.

The chemical composition is:—

Moisture	0.27%
Loss on ignition	2.65%
SiO_2	49.37%
Fe_2O_3	1.32%
Al_2O_3	4.07%
CaO	23.15%
MgO	19.53%
Total	100.36%

The 4 per cent alumina may be derived from antigorite, an altered product of diopside, or it may indicate that the diopside is an alumina-bearing variety.

Needles of dipyrite are sometimes contained in the diopside and thus replace it. The diopside is further replaced by lithia mica.

Tremolite: Generally in white prisms or minute fibres sometimes radiated. Some basal sections show distinct prismatic cleavages intersecting in two directions at about 124°. Nm = 1.61. Z ∧ C = 18°. The maximum interference color gives rise yellow of the 2nd. order. Optic axis interference figure shows clearly biaxial positive character and large optic angle.

Tremolite prisms usually dissect chalcopyite (Pl. XI, Fig. 2) and include numerous dipyrite needles. The tremolite is therefore later than chalcopyrite and earlier than dipyrite.

Dipyrite: Crystals fibrous and radiated. The color in hand-specimens is generally white or sometimes greenish. Colorless in thin section. Refringence low and negative. No = 1.53 approximately. Negative elongation. Parallel extinction. Interference color yellowish white of the 1st. order. Optically uniaxial and negative, but the fibres usually so fine that no distinct interference figure is observed. Chemical test indicates chlorine.

Dipyrite needles are sometimes replaced by minute crystals of lithia mica. Their development usually follows the cleavages of calcite or dolomite, exhibiting a grating appearance under crossed nicols. Where the metasomatic process has been accomplished, the whole mass of carbonate may entirely be altered into needles of dipyrite and then often in radiated spherulite aggregates. Another process of development consists of transformation of carbonate into a dirty earthy mass before the generation of transparent dipyrite needles.

Lithia mica: It occurs as minute crystals either in chondrondite or in the veinlets of dipyrite. Opitically biaxial and negative. Optic angle moderate. It may be muscovite, but the crystals are too few for detailed identification.

Antigorite: Generally in large prismatic crystals (Pl. VI, Fig. 1) sometimes radiated and pseudomorphic after diopside. Color greenish white. Hardness = 2. Nearly colorless in thin section. (010) and (001) cleavages both distinct. Positive elongation. Nm = 1.56. In a section parallel to optic plane or (010), which gives rise blue interference color of the 2nd. order, X is shown to be normal to (001) cleavage. The exceptionally stronger birefringencs observed is perhaps due to the excessive thickness of the section. Biaxial negative character is well shown in some section normal to the acute bisectrix or parallel to (001). 2V is small.

The chemical composition is:—

SiO_2	54.19%
Al_2O_3	4.86%
Fe_2O_3	1.65%
CaO	4.31%
MgO	25.02%
Na_2O K_2O	0.48%
H_2O (moisture)	0.25%
Loss on ignition	9.69%

The higher silica content is supposed to be from some scapolite mixed with the crystals of antigorite.

Thuringite: Cleavage distinct. Positive elongation. Pleochroism: Z = Y = dark green, and X = nearly colorles. Interference color: white in the 1st. order. Optically biaxial and negative. Optic angle moderate.

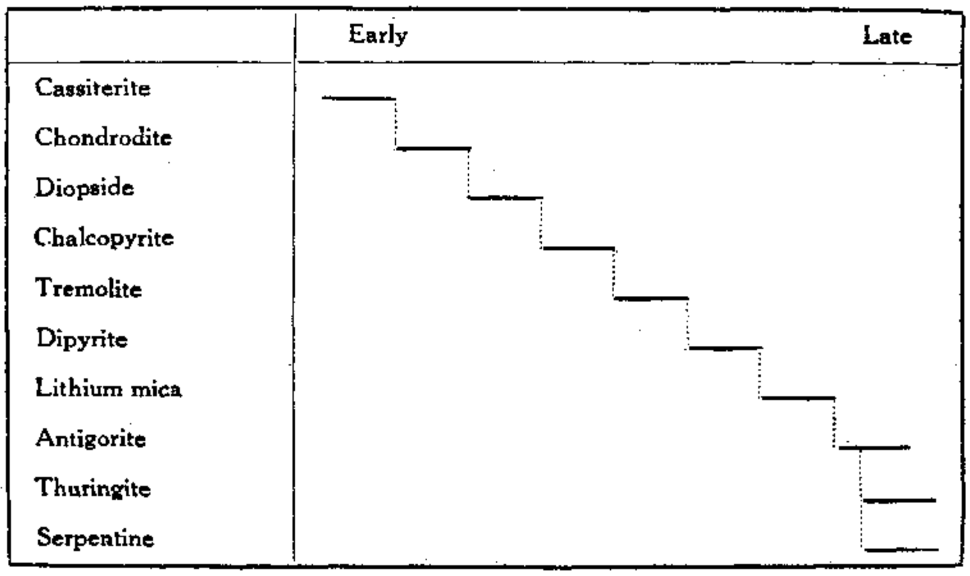
Serpentine: It is generally massive in serpentinisation of the fibres of probably of tremolite?

Aragonite: It is probably a supergene mineral. Refringence notally different in different directions. Birefringence extreme. (—) 2V small.

The paragenesis of the gangue minerals is much more obscure than that of the ore minerals, for they usually develop separately without mutual contact. There are, however, certain minerals whose genetic relations are distinct. A general idea of the succession of the gangue minerals is shown in the following table.

Table VI

The paragenesis of the gangue minerals from the Peichenglung Mine



In the above table the cassiterite and chalcopyrite, though not the gangue minerals, are inserted for denoting the paragenetic relation between the gangue and the ore minerals.

2. *From the Chuanyenpei pipe*

Vesuvianite: Generally occurring as a few prismatic crystals. Color brown. Brownish in thin section. Cleavage indistinct and parallel to elongation. No = 1.715. Negative elongation. Interference color is yellowish in the first order. Optically negative and uniaxial as inferred from some uncentered optic interference figure.

It usually include wollastonite prisms, which is probably the result of replacement.

Mizzonite: Occurring in prismatic crystals and sometimes in great quantity. Color greenish white. Colorless in thin section. (100) and (110) cleavages distinct (Pl. XI, Fig. 3). Negative uniaxial character easily recognised in some basal sections.

The chemical composition is as below:—

SiO_2	36.26%
Al_2O_3	34.02%
Fe_2O_3	0.99%
CaO	19.80%
Na_2O	6.98%
CO_2	3.30%
Cl	1.45%
	102.80%

The composition may be written as Ma_{30} Me_{70} according to Winchell's table[1]. The mizzonite is distinctly replaced by both salite and hornblende, with salite crystals sometimes developed in mizzonite. The contacts of the mizzonite prisms are usually filled in by chalcopyrite (Pl. XII, Fig. 1), indicating probably replacement origin.

Grossularite: In hand-specimens it is easily recognised as pinkish brown crystals. Hardness high. Colorless to brownish in thin section. Cracks abundant. Exhibits anomalous double refraction. Nm = 1.755. Dodehedral twinning common. Interference color is white in the 1st. order. Optically biaxial and positive. Optic angle large.

The cracks of grossularite are usually invaded by gashes of diopside or filled in by quartz.

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[1] A. N. Winchell; Elements of optical mineralogy, Part. II 1927, p. 346.

Quartz: It generally occurs without crystal outline. Positive uniaxial character is exhibited in some sections.

Certain quartz grains replace albite and are distinctly dissected by diopside or salite.

Diopside: Colorless in thin section. Interference color reddish yellow in the 2nd. order (0.03). $Z \wedge C = 38°$. Nm a little less than 1.70. Positive elongation. Prismatic cleavages distinct. Optic plane parallel to elongation. Optically positive and biaxial. 2V large.

The diopside often includes grains of dipyrite and is replaced by them.

Albite: Crystals prismatic. Albite twinning indistinct due to alteration. Nm<quartz. Exhibits positive and biaxial optic properties. Optic angle is large.

Wollastonite: It occurs in white radiated fibres. The cracks perpendicular to elongation or (100) cleavage, are abundant. Nm. = 1.62. Optic plane perpendicular to (100) cleavage or elongation. Two directions of cleavage are observed in a section parallel to the optic plane, in which the interference color gives rise yellow of the 1st. order. $X \wedge C = 34°$. Optically negative and biaxial as indicated in some section nearly perpendicular to one optic axis.

In some specimens the wollastonite seems to be replaced by gashes of diopside while in others it dissects salite and truncates grains of dipyrite. Its development is, thus, in two periods, one before diopside and other after salite and dipyrite.

Hornblende: It occurs only in a few short prisms or grains. Basal sections show distinctly two directions of prismatic cleavage. Pleochroism dark green and yellowish green.

Andesine: They are generally in prismatic crystals. Its mean index is higher than that of the Canada balsam. Optically positive and biaxial. 2V large. It is sometime replaced by salite or hornblende.

Salite: Basal sections show distinctly two directions of prismatic cleavage intersecting at about 92°. Maximum interference color gives rise green in the 2nd. order. Nm = 1.72. $Z \wedge 110 = 45°$. (+) 2V large.

This mineral may be either salite or augite. But, judging from its well defined extinction or less dispersion, it is determined to be salite.

Big crystal of salite usually contains veinlets of chalcopyrite and is itself dissected by the grains of dipyrite.

Dipyrite: It occurs in massive grains containing a notable amount of inclusions probably of carbonaceous matter. Nm = 1.55. Interference color is white gray in the 1st. order. Interference figure is generally too faint for detailed identification. Chemical test indicates the presence of chlorine.

Apatite: It occurs only in a few crystals.

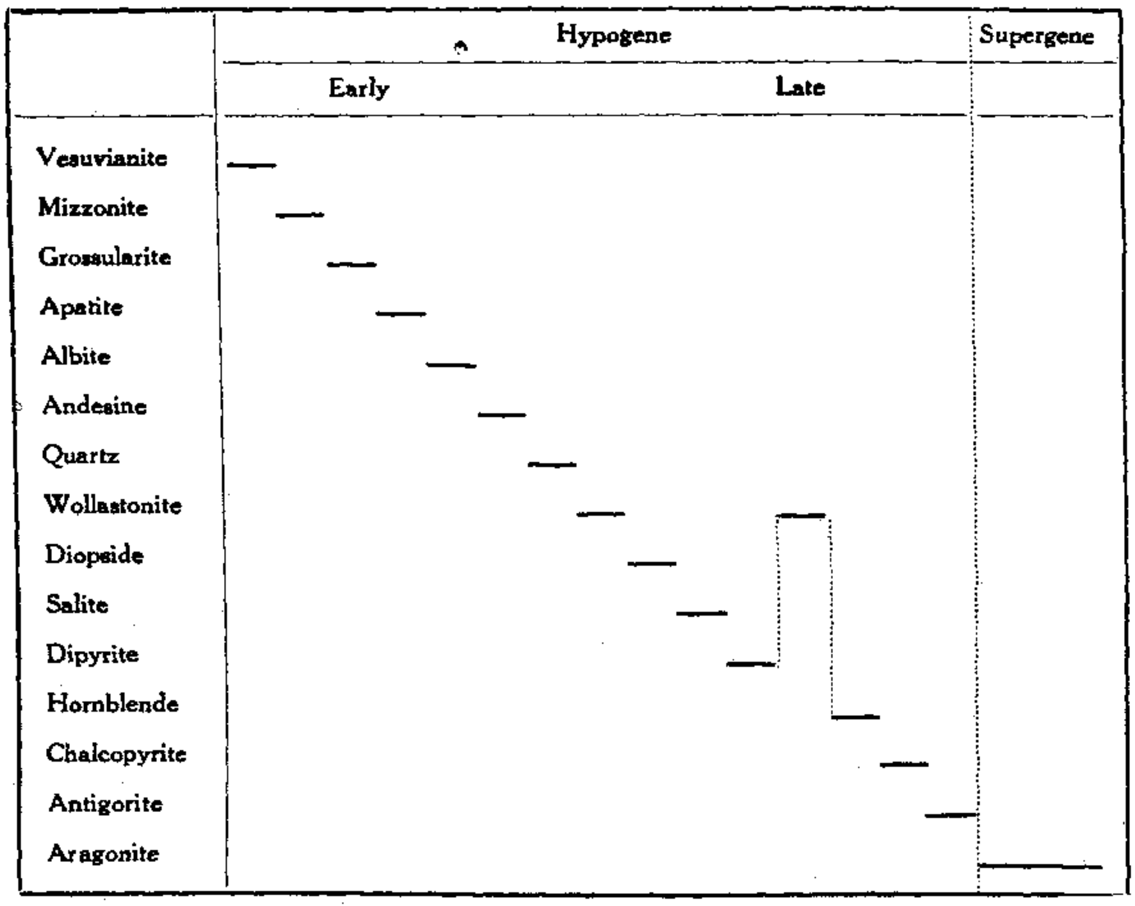
Antigorite: It occurs only in a few tabular crystals. Positive elongation. Optic plane is parallel to the cleavage. Optically negative and biaxial.

Aragonite: It occurs as veinlets in grossularite or other minerals and is probably supergene in origin. Negative biaxial optic property easily recognised. Optic angle small.

The succession of the above minerals is outlined in the following table, although the paragenesis of some is not yet quite clear.

Table VII.

The paragenesis of the gangue minerals from the Chanyenpei mine.



3. *From the Taoshihhu pipe*

Mizzonite: Partly altered to sericite. Cleavages distinct. Birefringence is a little above 0.025. Optically negative and uniaxial.

The mizzonite sometimes replaces arsenopyrite by projecting gashes into the latter and is dissected by numerous veinlets of fluorite.

Fluorite: It generally occurs in white or reddish grains. Octahedral cleavages distinct. Negative relief. Isotropic.

The veinlets of fluorite in mizzonite are sometime transected by hornblende crystals. The last named mineral may also develop along the cracks of the first. Fe-Tourmaline often contains abundant residual grains of fluorite or develops along the contacts of the fluorite crystals. Both hornblende and Fe-tourmaline are, thus, later than fluorite. In some specimens veins of quartz and fluorite are included in chalcopyrite, and they are thus later than chalcopyrite. There are therefore two periods of fluorite formation, one before Fe-tourmaline and the other after chalcopyrite.

Fe-Tourmaline: They occur in long prismatic crystals. Pleochroism: Z=blue; X=pale violet gray. Absorption: $Z>X$. At the opposite ends of the vertical axis, blue colors are often distributed in zones. Interference color is in the third order. Optically negative and uniaxial.

Garnet: Color ranges from brown to greenish, showing distinct optic anomalies. Dodecahedral twinning common. Cracks abundant. Most probably belongs to grossularite. Usually it contains fluorite residual grains and along its cracks diopside is sometimes developed.

Apatite: The grains of apatite in the thin slides are generally too few for detailed identification. The refringence is high and birefringence very weak. Chemical test indicate the presence of phosphorous.

Diopside: It occurs in long prismatic crystals or grains. Color green. Prismatic cleavages distinct. $Z \wedge C = 39^\circ$. Optically positive and biaxial.

Chalcopyrite usually forms veinlets along the cleavages or fractures of diopside.

Salite: It is also in green color, but the extinction angle between Z and C is increased to about 45° instead of 39°. (+) 2V large.

Hornblende: It occurs in radiated prismatic crystals. (110) cleavages distinctly intersect at about 124° as shown in some basal sections. The pleochroic formula: Z=greenish blue, Y=bluish green, and X=yellow. The absorption is $X<Y<Z$. $N_m = 1.68$. $Z \wedge G = 25^\circ$. (−) 2V = large. Partly altered to chlorite.

Tremolite: Crystals prismatic or fibrous. Pleochroism is greenish yellow and green. From this point, the mineral seems to belong to actinolite. As shown in the following chemical analysis it contains a great amount of Al_2O_3 and is, thus, also intimately related to pargasite. The ferric oxide content is, however, insufficient either for actinolite or for pargasite and the latter is optically positive according to Prof. A. N. Winchell. The specific gravity of the tremolite is about 3. Prismatic cleavages intersecting at about 124° as shown by some basal sections, are distinct. Nm = 1.62. $Z \wedge C = 18^\circ$. Maximum interference color gives rise green of the 2nd. order (0.025). In a section perpendicular to X, the interference color is yellow in the 1st. order (0.011) Positive elongation. Optic plane is parallel to cleavage or elongation. By some section perpendicular to one optic axis it is proved to be positive and biaxial. Optic angle large.

The chemical composition is:—

Moisture	0.76%
Loss on ignition	0.67%
SiO_2	50.47%
Fe_2O_3	1.17%
Al_2O_3	14.53%
CaO	10.97%
MgO	20.57%
Total	99.14%

The prismatic crystals of tremolite usually constitute skeletons in chalcopyrite (Pl. XII, Fig. 2) or dissect pyrite and sphalerite in various directions, but when in contact with arsenopyrite, they do not show any metasomatic action probably due to selective replacement. Taking arsenopyrite as a nucleus, the tremolite prisms may sometimes form radiating crystals from it. They are also distributed in a ground mass of fluorite or dipyrite.

Muscovite: It occurs as minute crystals in veins in dipyrite. (−) 2V = moderate.

Quartz: A great amount of quartz grains occurs only in one hand-specimen. Positive uniaxial character is distinct.

Spinel: Occurring only in a few grains. The color is yellow. High relief. Isotropic.

Dipyrite: It is generally massive. Refringence is a little higher than that of the balsam. Interference color is reddish yellow in the 1st. order.

Lithia mica: There are two varieties of lithia mica. One occurs in short prisms or in anhedra. (001) cleavage distinct. Basal pseudohexagonal plates common. The pleochroism: X = colorless, and Z = greenish. (−) 2V = 0. The acute bisectrix X is nearly normal to (001). Chemical test indicates lithium.

Another variety may be protolithionite. Nm = 1.59. Pleochroism: Z = green, Y = greenish white, and X = yellow. Birefringence is strong. (−) 2V = small. Chemical test shows the presence of lithium. Lithia mica crystals usually transect chalcopyrite (Pl. XII, fig. 3).

Lithium tourmaline: It occurs only in a few grains. As associated with lithia mica, it is believed to be also a lithium variety, though further confirmation is necessary. Marked pleochrism: Z = blue, and X = colorless. The absorption is Z>X. Interference color gives rise blue of the 2nd. order. Optically uniaxial and negative. It is paobably later than lithia mica.

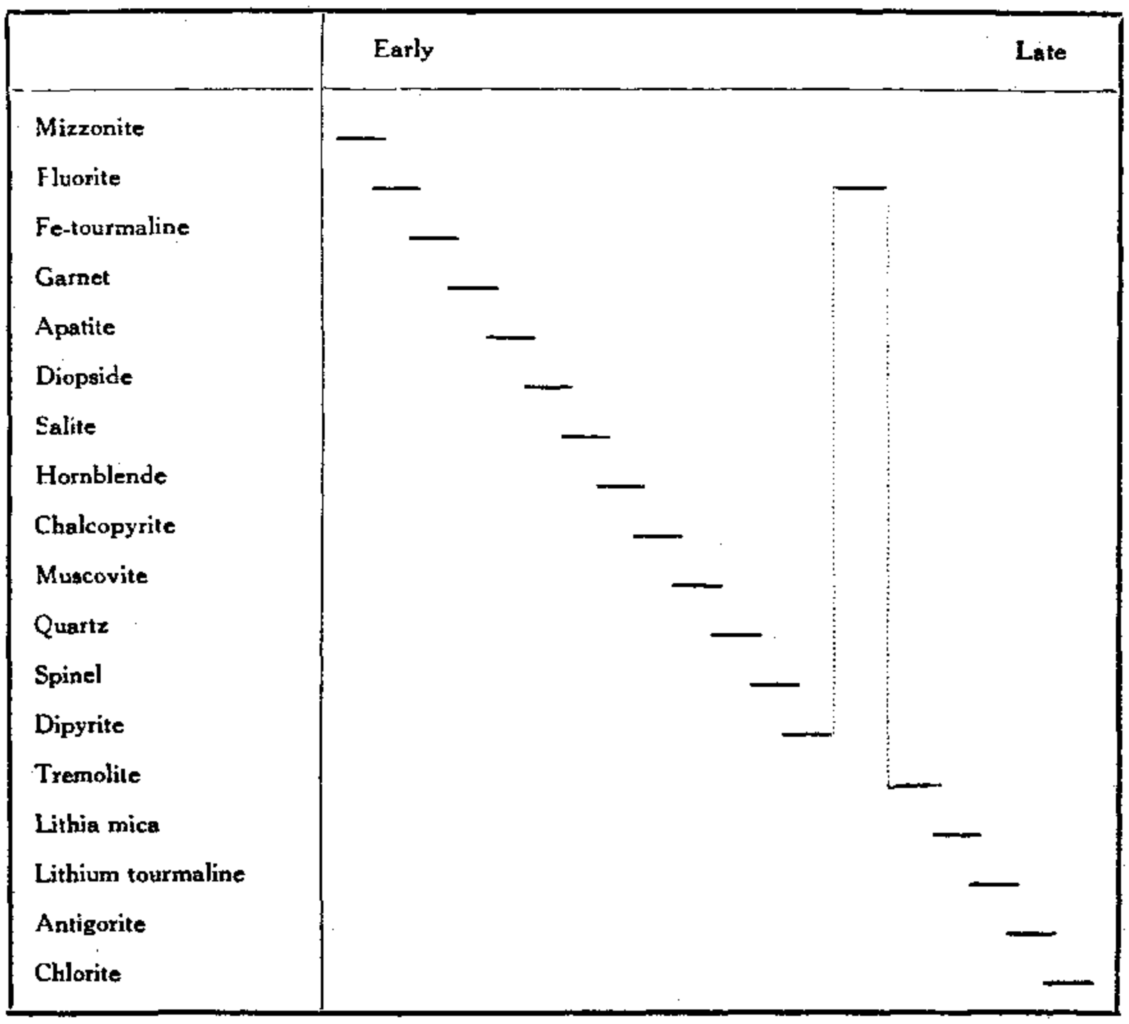
Antigorite: Crystals prismatic. Cleavages distinct. Positive elongation. Birefringence weak. It is generally altered from hornblende, diopside, and salite.

Chlorite: It is massive and chiefly as an alteration product of amphibole and pyroxene. Birefringence is nearly zero.

The succession of the minerals mentioned is enumerated as below:—

Table VIII

The paragensis of the gangue minerals from the Taoshihhu mine,



The ore mineral chalcopyrite is here inserted for showing the genetic relation between ore and gangue minerals.

4. *From the Tashunlung pipe*

There are only two gangue minerals recognised.

Lithium tourmaline: It occurs in fine needles sometimes radiated. Pleochroic formula: Z = bluish, and X = colorless. The absorption is $Z > X$. $No = 1.638$.

The chemical composition is:—

H_2O-	0.37%
H_2O+	8.78%
SiO_2	26.37%
Fe_2O_3	8.55%
Al_2O_3	35.51%
CaO	2.65%
MgO	6.16%
Na_2O	5.64%
Li_2O	0.20%
B_2O_3	7.47%
Total	100.00%

The optic properties of the mineral show essentially a lithium tourmaline though its Li_2O content is only 0.20 per cent.

Fluorite: They generally form white or purplish crystals. Octahedral cleavages are distinct.

5. *From the Puli pipe*

Quartz: It occurs in hypidiomorphic crystals. Often contains a great amount of opaque inclusions sometimes arranged in certain definite directions. Positive uniaxial character is easily recognised.

Scheelite: It occurs only in a few white pyramidal crystals. No. >1.77. Birefringence is about 0.016. Optically positive and uniaxial. Chemical test indicates tungsten.

Fluorite: They form greenish crystals. Sometimes with abundant inclusions, and their cleavage is distinct.

Mica: Generaly in short flakes. Pleochroic colors are greenish and colorless. (——) $2V = 0$.

Chlorite: It occurs in fine fibres. Positive elongation. Birefringence is about 0.004. Optically negative and biaxial. Optic angle small. Optic plane parallel to elongation.

The succession of the above minerals:—

(1) Quartz (the earliest) (2) Scheelite (3) fluorite (4) mica (5) Chlorite (the latest).

A summarized table showing the distribution of minerals is the cassiterite-arsenopyrite pipes in southern Hunan.

Minerals	Peicheng-lung	Liutzelung	Chuanyen-pei	Tashihhu	Tashunlung	Puli
Arsenopyrite	o	×	o	o	o	o
Cassiterite	o			o	×	×
Chondrodite	×					
Vesuvianite			×			
Mizzonite			×	o		
Grossularite			o			
Garnet				×		
Albite			×			
Andesine			×			
Quartz			×	×		×
Wollastonite			×			
Diopside	o		×	×		
Salite			×	×		
Dipyrite	o		×	×		
Hornblende			×	×		
Fluorite				×	o	o
Fe-tourmaline				×		
Apatite			×	×		
Pyrrhotite		×		×		×
Pyrite	×	×	×	×	×	×
Chalcopyrite	o	×	×	o	o	×
Sphalerite	×	o	×	×	×	o
Stannite	×					×
Enargite	×					
Tennantite	×		×			
Bornite	×				×	
Hematite					o	
Scheelite						×
Li-tourmaline				×	×	
Li-mica	×			×		
Mica						×
Muscovite				×		
Tremolite	×			o		
Spinel				×		
Antigarite	o		×	×		
Chlorite	×			×		×
Chalcocite					×	
Aragontine	×		×			
Serpentine	×		×			

× occurs in small quantity

o occurs in appreciable quantity.

VI. PROCESS OF FORMATION OF THE CASSITERITE-ARSENOPYRITE PIPES

From a critical study of the pipes just described, it is obvious that the earlier minerals such as arsenopyrite and cassiterite, usually form the outer zones, and from these inwards chalcopyrite and silicate minerals gradually take their importance. The outer zones of the pipes seem, thus, to have been developed first and are, then, followed by chalcopyrite and silicates of the inner zone. The detailed processes of formation of these pipes are of course difficult to determine, but from the well arranged concentric growth of their mineral constituents and the definite order of crystallization from outside to inside, it may be suggested that diffusion phenomena has played an important part in their formation. The ore solution presumablly under high temperature and pressure has injected into the limestone along fissures etc. By diffusion, this solution gradually worked outwards and as soon as it reached suitable position, the outer zone marked by cassiterite and arsenopyrite minerals all having a higher melting point was formed first. This zone reacted then as an obstacle for any further spreading or diffusion of the solution and when temperature gradually lowered down, minerals like chalcopyrite etc. will naturally be concentrated in the central portion of the pipe. Thus, although the spreading of the solution was in a centrifugal way i. e. from inside to outside, the actual growth of minerals was in fact according to a centripetal direction i. e. from the periphery working gradually backward towards the center. In view of the presence of vugs in some of the ore bodies and the frequent swelling and contraction of the pipes, it is believed that the physical nature of the country rock including rock openings etc. should be the main cause for the localization of the pipes, The rock opening does not necessary to be long and continuous, since under the excessive pneumatolytic pressure of the ore solution, it may inject initially through a small opening or fissure but may make the room for itself on its way upwards. The mode of injection is therefore well comparable to the formation of a volcanic neck. During the formation of the pipes, replacement and filling may have both taken place, but the former seems to be more important.

VII. DISCUSSION ON THE POSITION OF THE PIPES IN THE CLASSIFICATION OF ORE DEPOSITS

The tin-arsenic deposits showing a cylindrical form is widely distributed in S. W. China as well as its neighbouring countries. This mineralized belt has been traced from Hunan southwestward through Kuangsi, Yunnan, Burma, Siam and lastly to Malay Peninsula. Though much geological work has been done in the last named region, no attention seems to have been paid on the classification of the pipes. According to Prof. W. Lindgren[1] such pipes are provisionally classified under his hypothermal deposits, while in other textbooks of economic geology, definite conclusion on this problem is usually not given. In fact, the cassiterite-arsenopyrite pipes in Hunan are usually intimately associated with the typical hypothermal sphalerite veins and are sometimes located far distant from the granite-limestone contact. It would thus seem reasonable that the pipes should have been included in the hypothermal deposits. On the other hand, the gangue minerals in the pipes such as wollastonite, diopside, tremolite etc. are more common in contact metamorphic deposits than in hypothermal type. Further, the orbicular structure formed by pipe-like arrangement of minerals is also more characteristic to the former type. In view of these points, the pipes would belong to the contact metamorphic deposit. But, the silicates in the contact deposits are generally earlier than the sulphides, while the gangue minerals in the pipes are often later than the ore minerals such as arsenopyrite, chalcopyrite etc. In addition, in contact deposits gangue minerals do not commonly replace sulphides, while in the pipes the chalcopyrite is frequently replaced by the gangue minerals. All of these indicate that the cassiterite-arsenopyrite pipe forms really a special and unique type in mineral deposits, being unfitted to be classified either under hypothermal or under contact types. It seems desirable therefore to propose a new class of deposits the "tin-arsenic pipes" to be inserted between the hypothermal and the contact metamorphic divisions.

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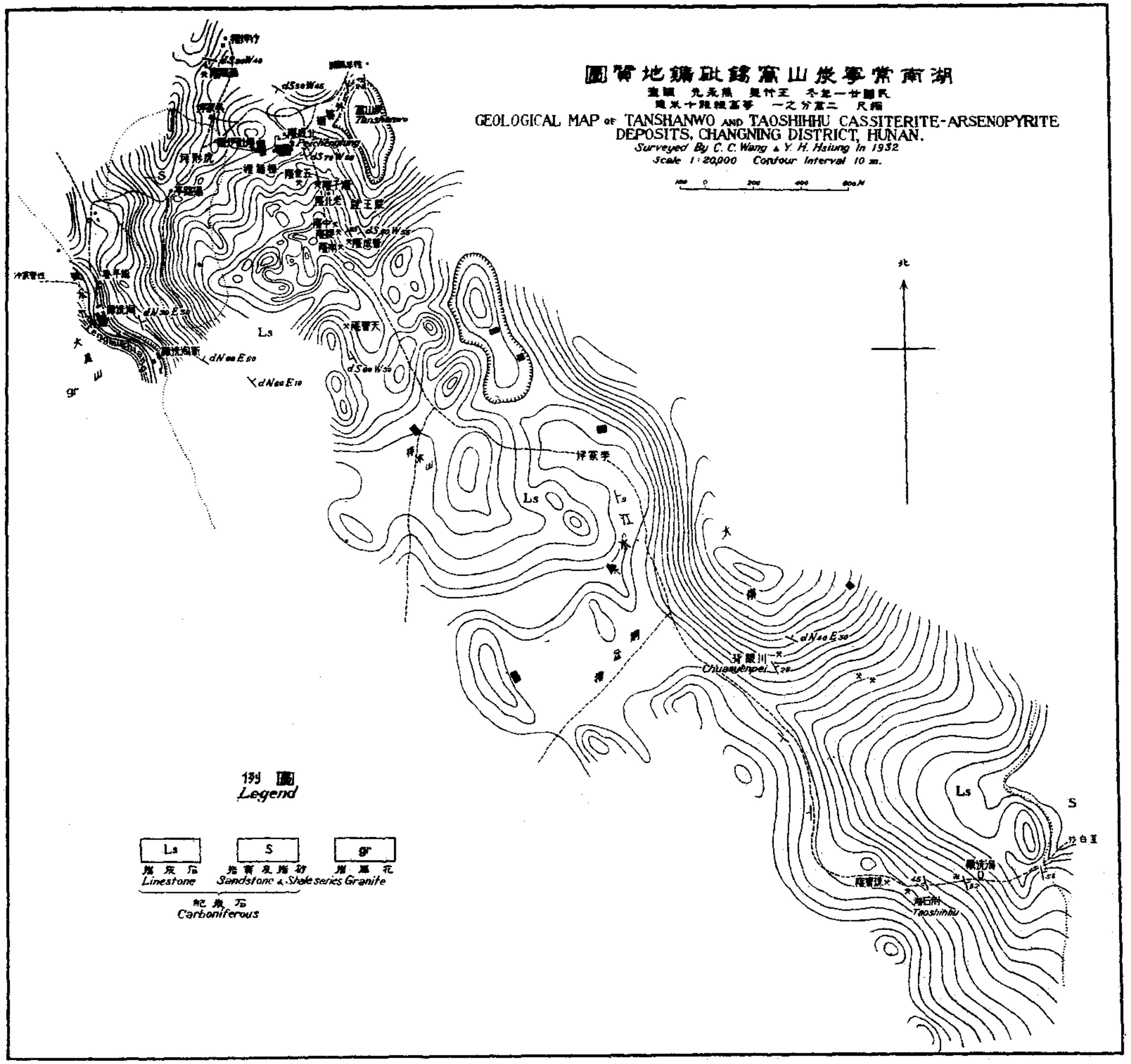
[1] W. Lindgren: Mineral deposits, fourth edition, 1933, pp. 658.



湖南常寧炭山窩錫砒鑛地質圖

民國廿一年冬 王竹泉 熊永先 調查

縮尺 二萬分之一 等高線距十米達

GEOLOGICAL MAP OF TANSHANWO AND TAOSHIHHU CASSITERITE-ARSENOPYRITE DEPOSITS, CHANGNING DISTRICT, HUNAN.

Surveyed By C. C. Wang & Y. H. Hsiung In 1932

Scale 1 : 20,000 Contour Interval 10 m.

Explanation of Plates II-XII

PLATE II

1. 由北成窿北望古老壯年地面之景
   View of an old erosion surface of advanced maturity, north of Peichenglung.
2. 普利公司之古老壯地面
   Another view of the mature erosion surface, south of the Puli Mine.
3. 由大順窿向西南望蜈蚣嶺及雷形嶺之景
   View of Wukungling and Leihsingling, S. W. of the Tashunlung Mine.
4. 川眼背井口之景
   View of the Carboniferous metamorphosed limestone at the Chuanyenpei Mine.

PLATE III

1. 大順窿淘洗錫砂之景，背後爲古老壯地面之脊嶺
   View showing the native method of washing cassitite ore, Tashunglung Mine.
2. 北成窿之煆灰廠
   View of the ore roasting furnace of the Peichenglung Mine.
3. 普利公司全景
   Panoramic view of the Puli Mine.
4. 大順窿爐砒廠之景
   View of the arsenic furnace of the Tashunlung Mine.

PLATE IV

1. 円筒狀錫砒礦橫剖面 (北成窿)
   Cross section of a cassiterite-arsenopyrite pipe, from the Peichenglung Mine, natural size,
2. 円筒狀錫砒礦直剖面 (北成窿)
   Vertical section of the same pipe as in Fig. 1.

PLATE V

1. 錫砒礦石之帶狀結構 (北成窿地字莊)
   Banded structure of the cassiterite-arsenopyrite ore, natural size, from the Peichenglung Mine.
2. 錫砒礦石內之放射狀透輝石結晶 (北成窿)
   Radiated crystals of diopside in the ore, natural size, from the same mine as in Fig. 1.

PLATE VI

1. 錫砒礦石內之葉狀蛇紋石 (北成窿地字莊)
   Prismatic crystals of antigorite in the cassiterite-arsenopyrite ore, Peichenglung Mine. Natural size.
2. 円筒狀錫砒礦直剖面 (北成窿)
   Vertical section of another cassiterite-arsenopyrite pipe, (⅔ of natural size, from the same mine as in fig. 1.)

· PLATE VII

1. 円筒狀錫砒礦橫剖面 (北成窿)
   Cross section of the same pipe as in Pl. VI, Fig. 2.
2. 電氣石脈中之礦液引導裂隙 (倒石湖)
   A tourmaline vein from the cassiterite-arsenopyrite deposits of Taoshihhu, showing the original fissure for introduction of ore solution, natural size.
3. 毒砂被錫石交換之狀況 (北成窿地字莊)
   Replacement of arsenopyrite by cassiterite from the Peichenglung Mine, × 110.
4. 閃鋅礦交換黃銅礦及被黃錫礦交換之狀況 (北成窿)
   Replacement of chalcopyrite by sphalerite which is again replaced by stannite. From the same mine as in Fig. 3. × 120.

PLATE VIII

1. 黃銅礦被黃錫礦從中心向外交換之狀況 (北成窿)
   Replacement of chalcopyrite by stannite from centre outwards, constituting the so called centrifugal replacement. From the Peichenglung Mine × 110.
2. 黃銅礦內之黃錫礦細脈 (北成窿)
   Replacement veinlets of stannite in chalcopyrite, resembling an intergrowth texture from the same mine, × 210.
3. 黃錫礦內黃銅礦組成之方格狀結構 (北成窿)
   Exsolution texture of Chalcopyrite in stannite. From the same mine as above. × 210.
4. 斑銅礦交換第一期沈積之黃銅礦及被第三期黃銅礦交換之狀況 (北成窿)
   Replacement of the 1st. generation Chalcopyrite by veinlets of bornite which is in turn replaced by Chalcopyrite of the 3rd. generation. From the same mine as in Fig. 3. × 100.

PLATE IX

1. 斑銅礦被第三期黃銅礦交換之狀況 (北成窿)
   The third generation chalcopyrite in bornite. From the same mine as in Pl. VIII, Fig. 4, × 100.
2. 毒砂內之附生礦石細脈 (川眼背)
   Veinlets of gangue mineral in arsenopyrite, Chuanyenpei Mine, × 100.
3. 磁黃鐵礦內黃鐵礦之殘晶及黃銅礦內磁黃鐵礦之殘晶 (倒石湖)
   Residual grains of pyrite in pyrrhotite and pyrrhotite islands in chalcopyrite, Taoshihhu Mine, × 100.
4. 磁黃鐵礦被黃銅礦交換之狀況 (倒石湖)
   Replacement of pyrrhotite by chalcopyrite. From the same mine as above × 100.

PLATE X

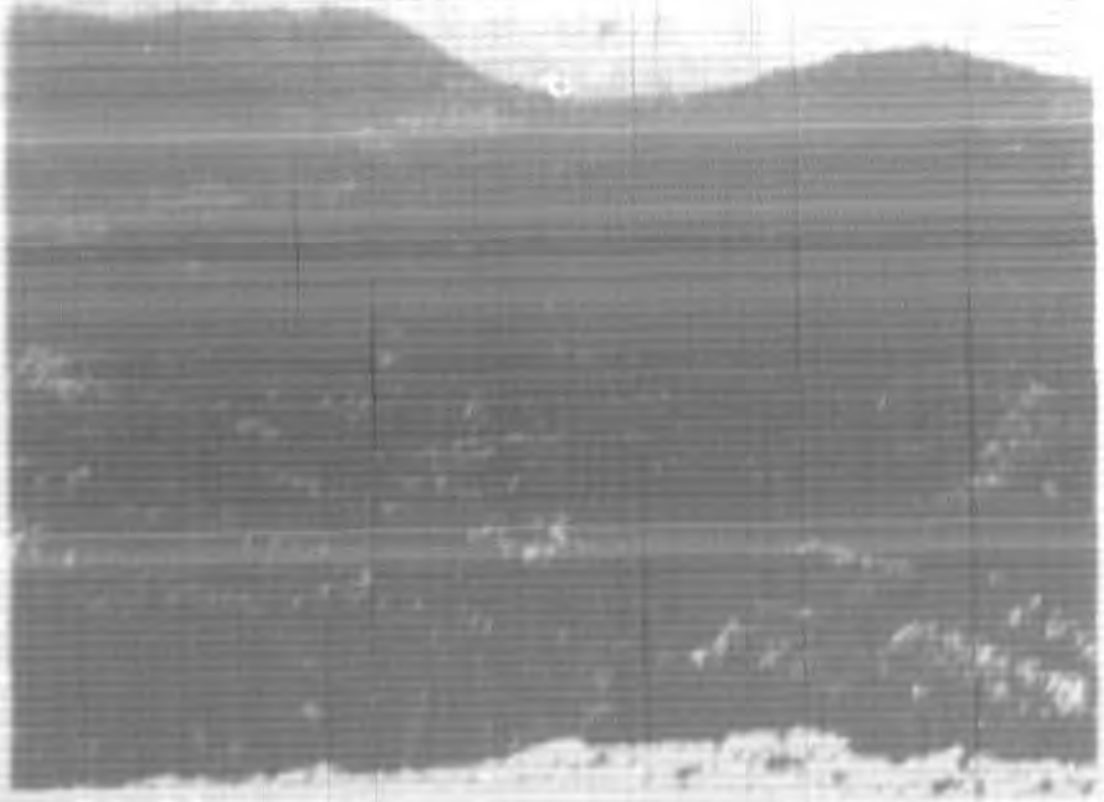
1. 黃銅礦及磁黃鐵礦在閃鋅礦內組成之不混合點狀結構 (大順窿)
   Unmixing texture of chalcopyrite & pyrrhotite in sphalerite from the Tashunlung Mine, × 100.
2. 黃銅礦被斑銅礦交換之狀況 (大順窿)
   Replacement of chalcopyrite by bornite from the same mine, × 100.
3. 毒砂內之黃鐵礦脈 (普利公司)
   A pyrite vein in arsenopyrite, Puli Mine. × 100.
4. 黃銅礦與毒砂接觸處被閃鋅礦交換之狀況 (普利公司)
   Replacement of chalcopyrite by sphalerite along its contact with arsenopyrite. From the same mine as in Fig. 3, × 100.

PLATE XI

1. 顯微鏡下錫石色澤之帶狀組織 (北成窿)
   Zonal distribution of the colors in cassiterite from the Peichenglung Mine, × 45.
2. 黃銅礦被透角閃石柱晶交換之狀況 (北成窿)
   Replacement of chalcopyrite by tremolite prisms. From the same mine, × 45.
3. 顯微鏡下中柱石之底剖面 (川眼背)
   A basal section of mizzonite from the Chuanyenpei Mine, × 38.

PLATE XII

1. 中柱石被黃銅礦沿晶體接觸交換之狀況 (川眼背)
   Mizzonite replaced by chalcopyrite along its crystal contacts and cracks from the Chuanyenpei Mine, × 11.
2. 透角閃石交換黃銅礦 (倒石湖)
   Tremolite replacing chalcopyrite, Taoshihhu Mine, × 45.
3. 黃銅礦被鱗雲母晶體分割交換之狀況 (倒石湖)
   Chalcopyrite dissected by lithia mica crystals; from the same mine as in Fig. 2, × 45.



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2

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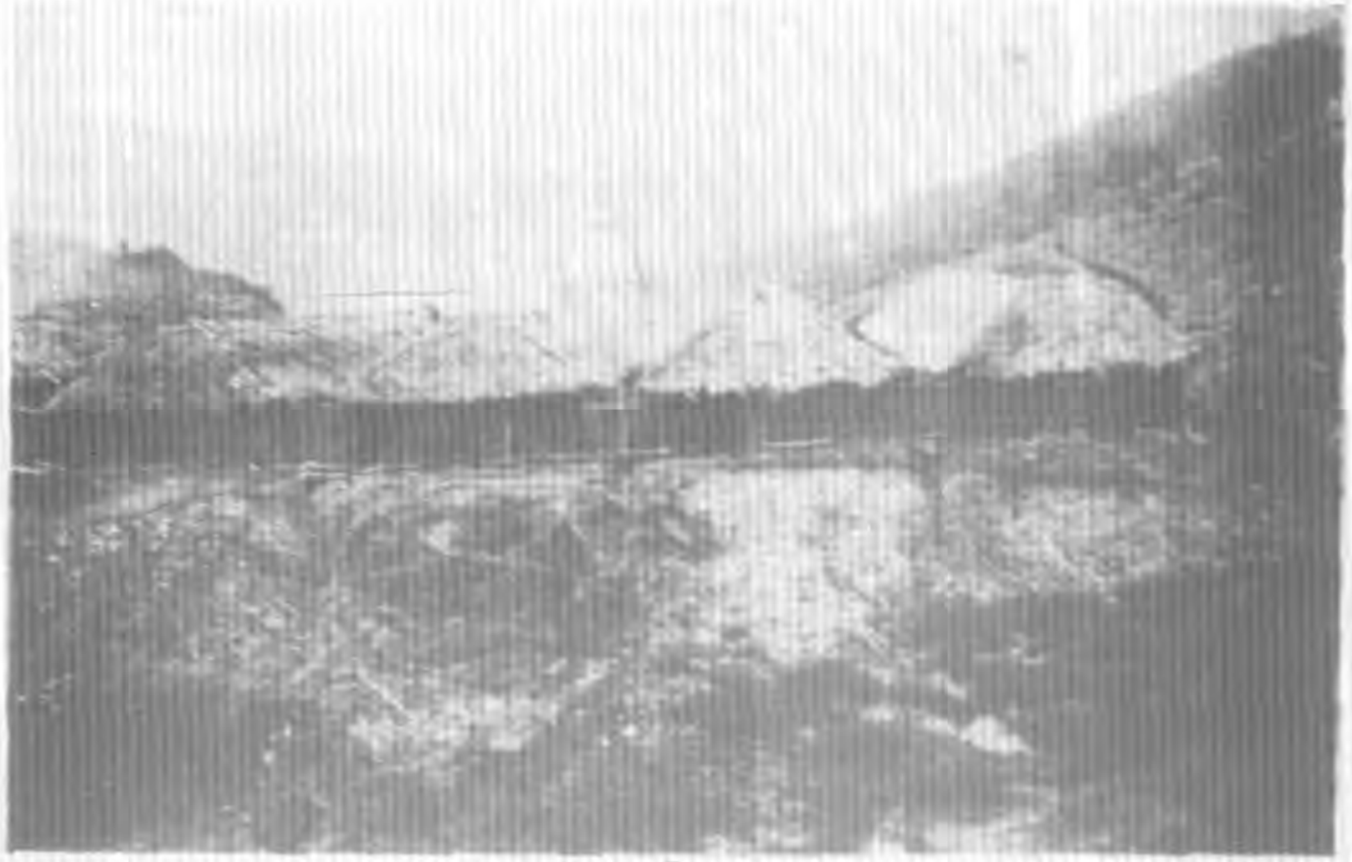

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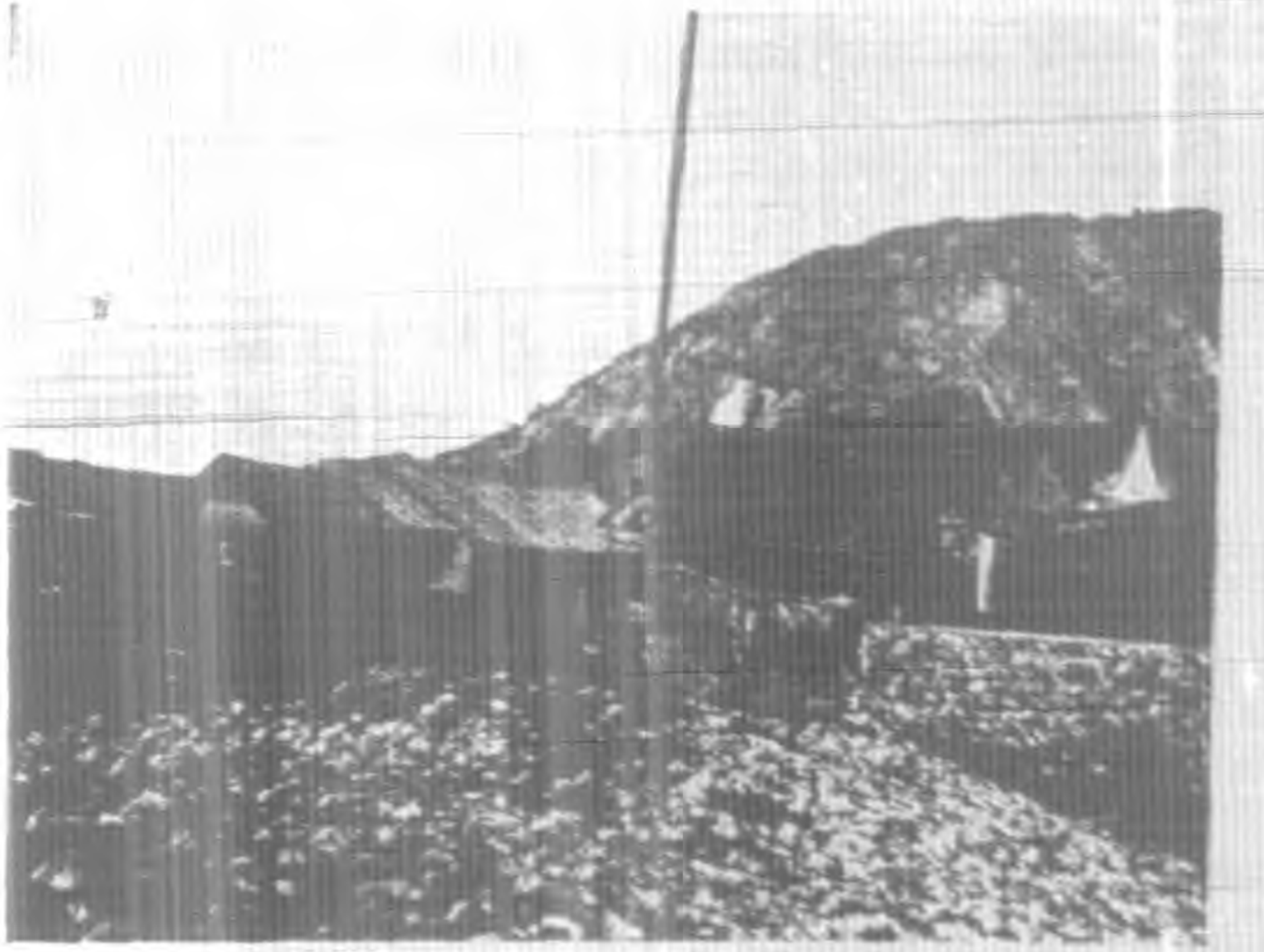

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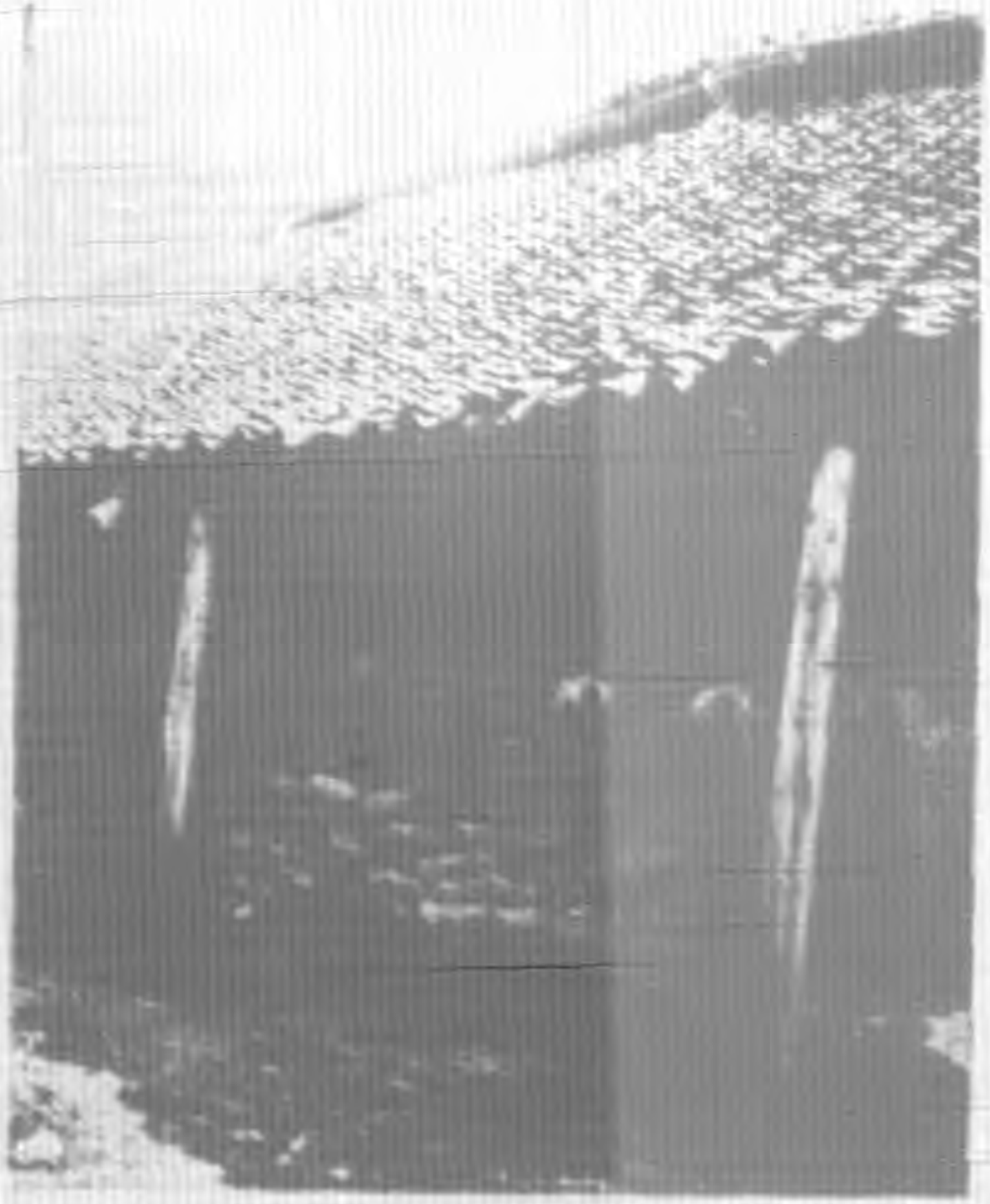

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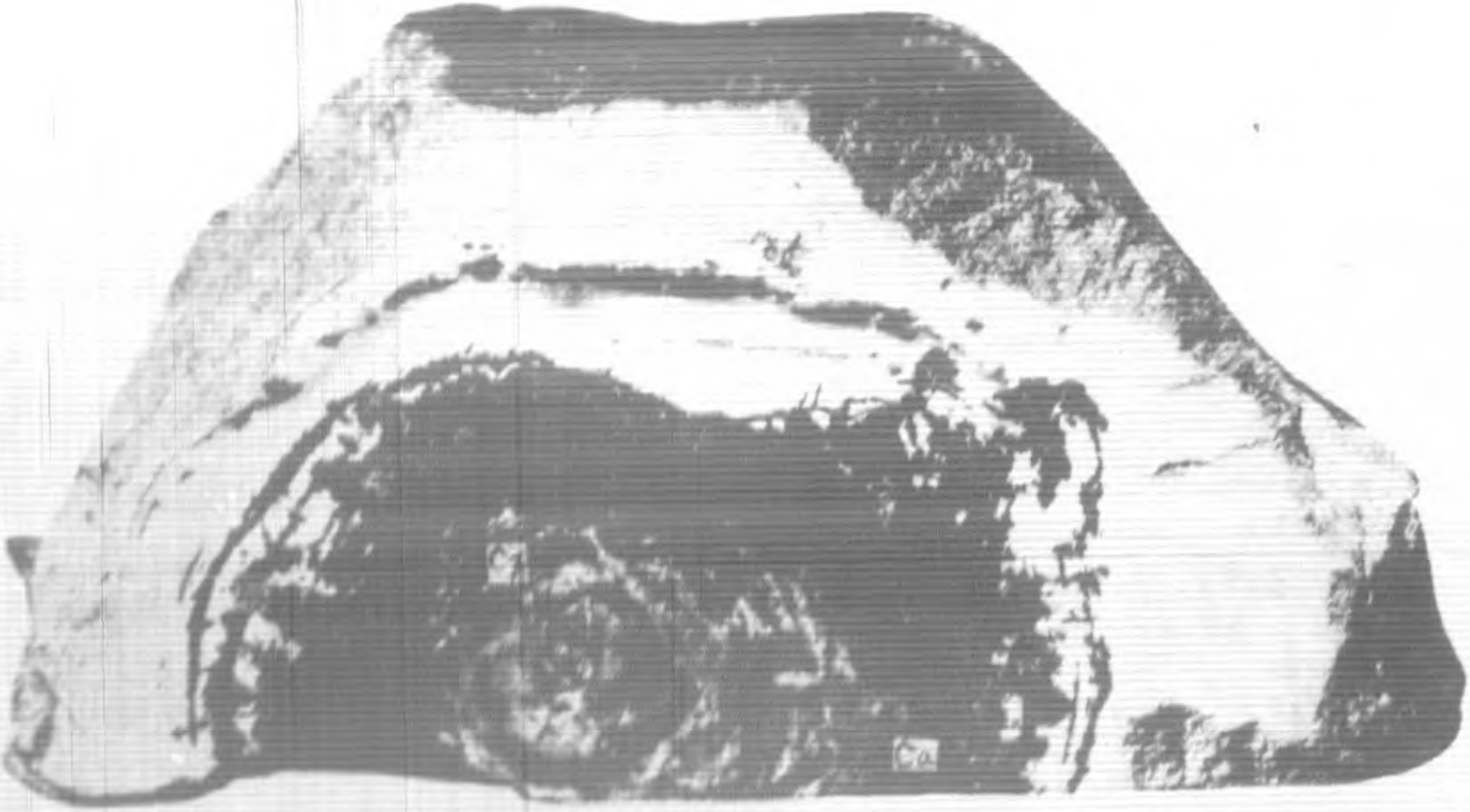

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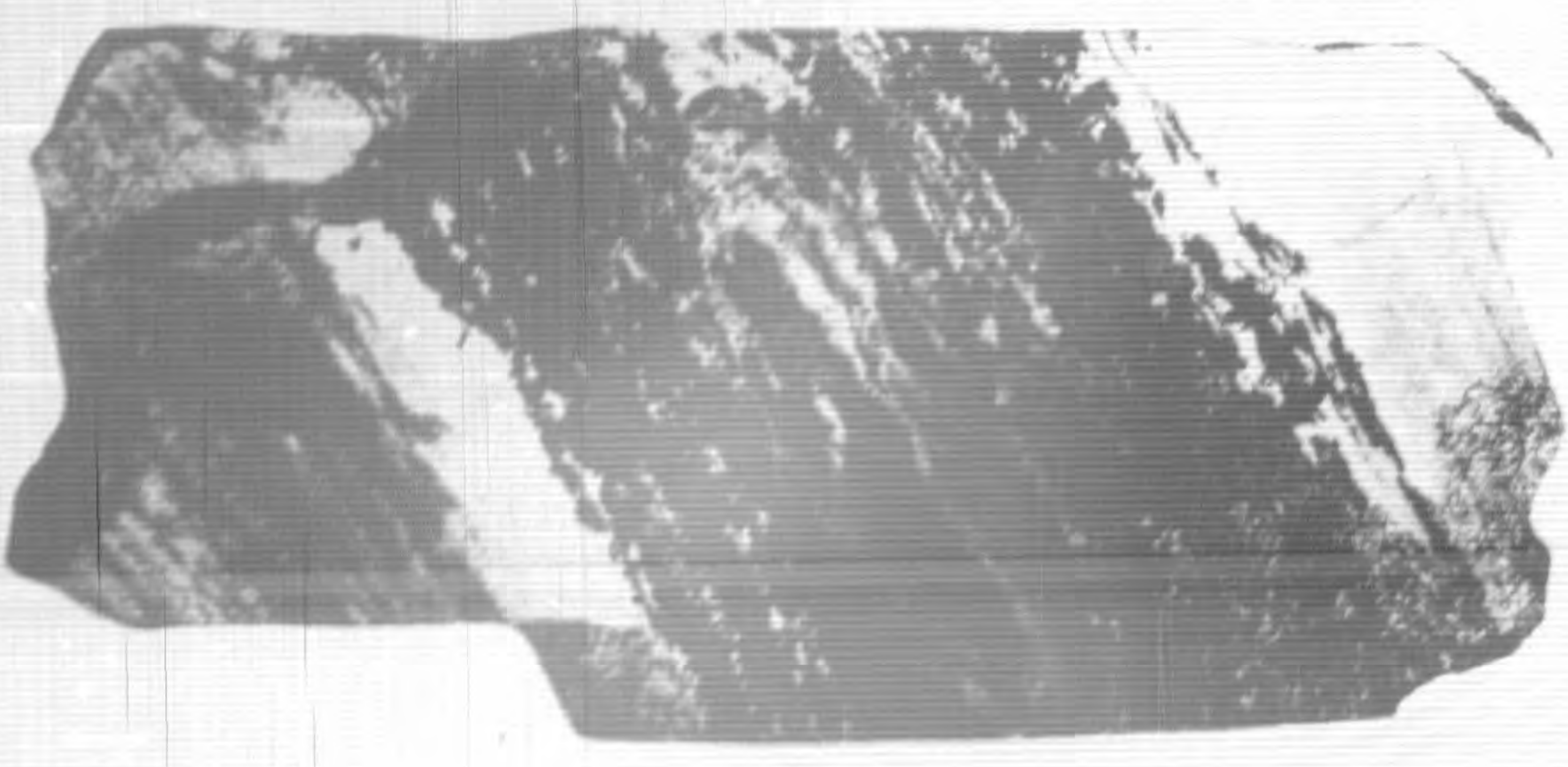

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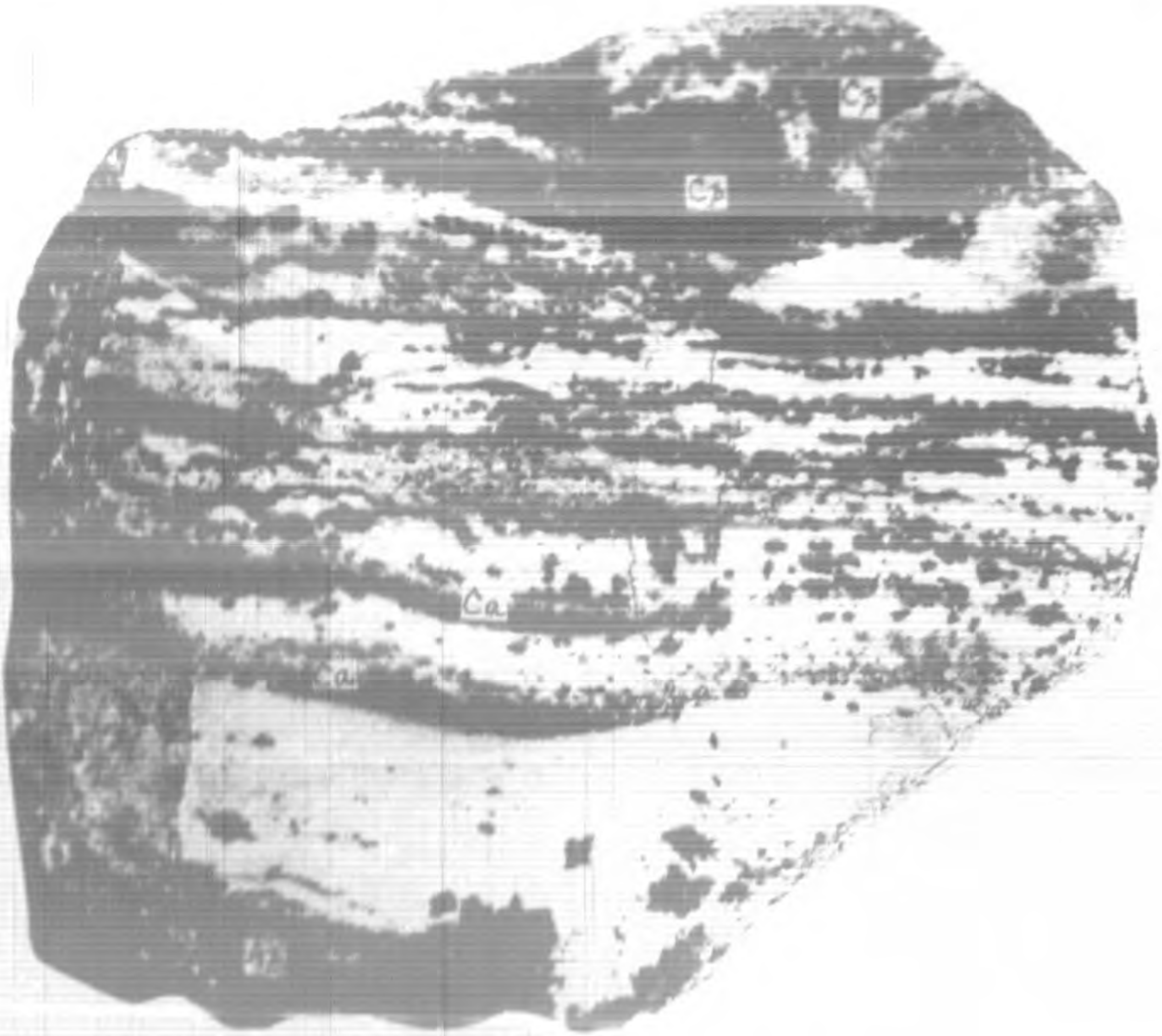

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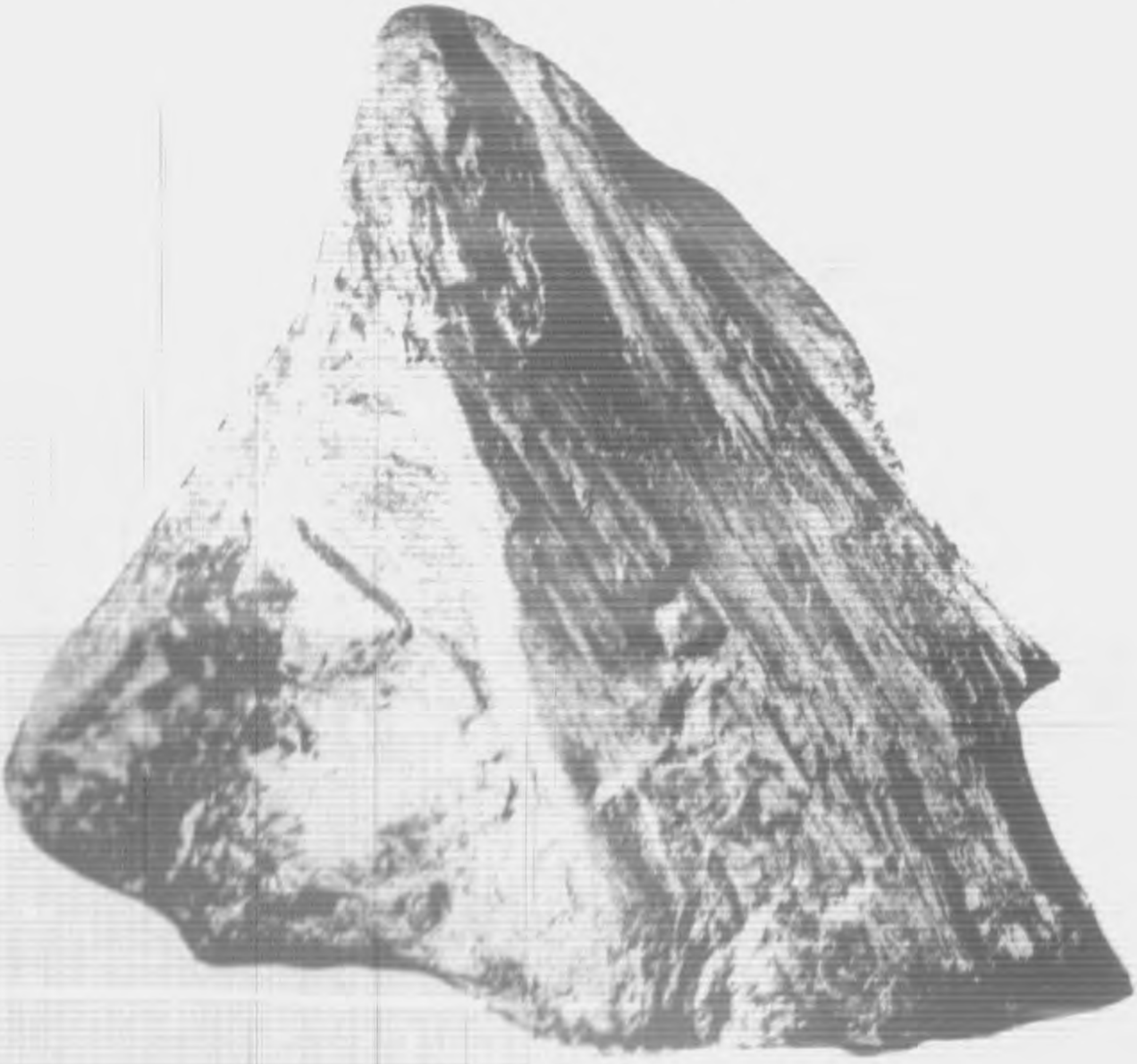
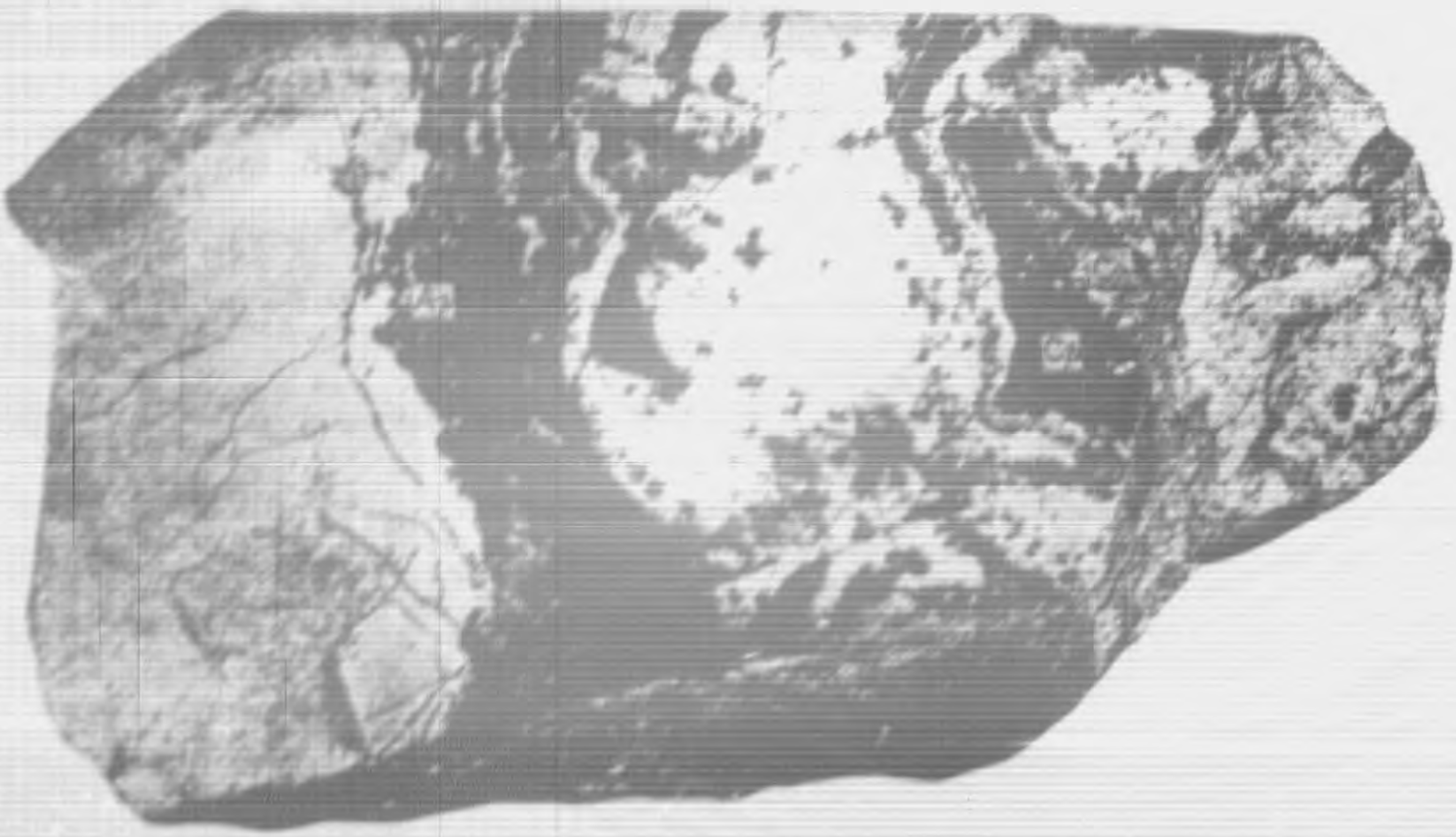


1



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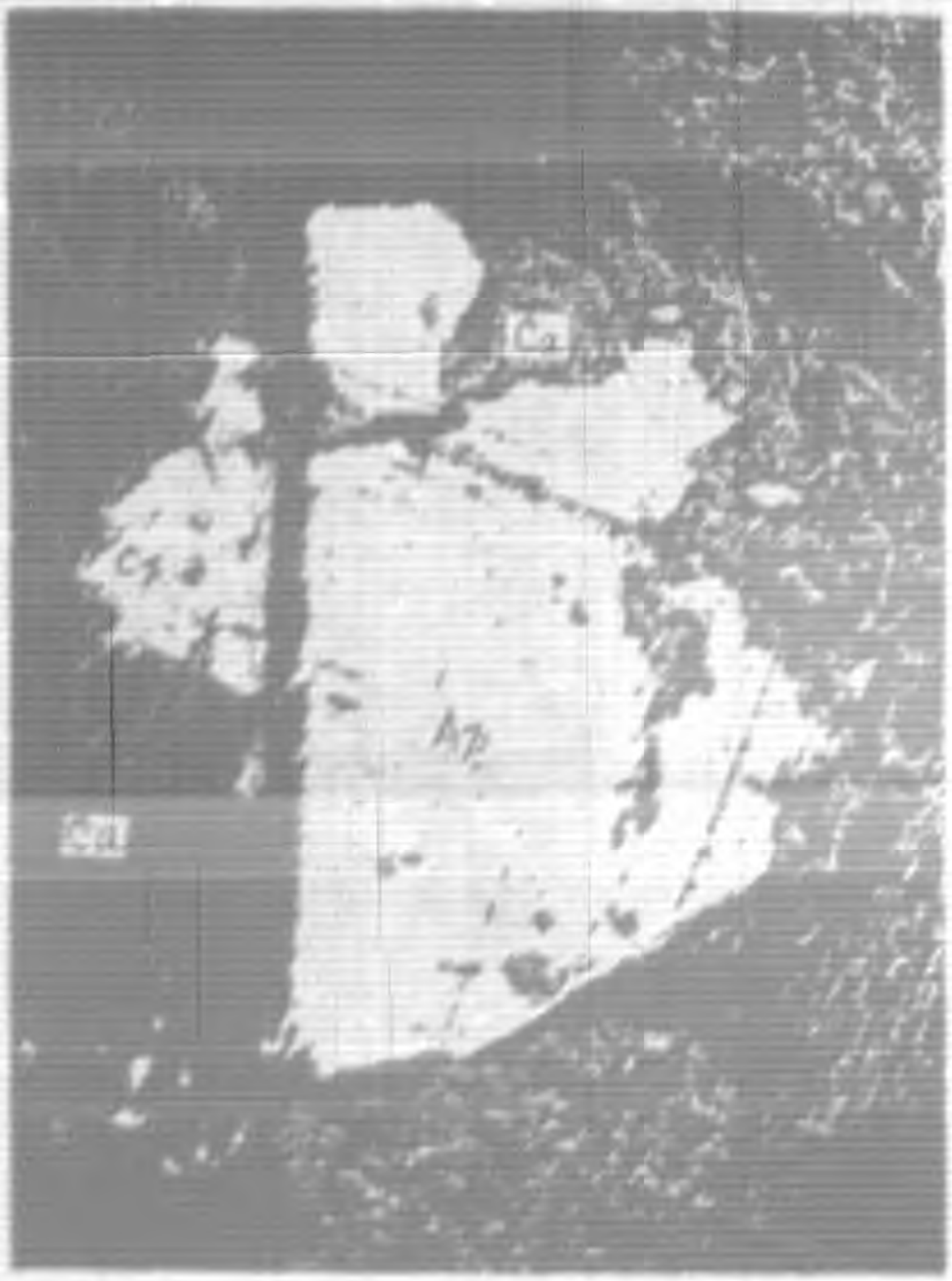

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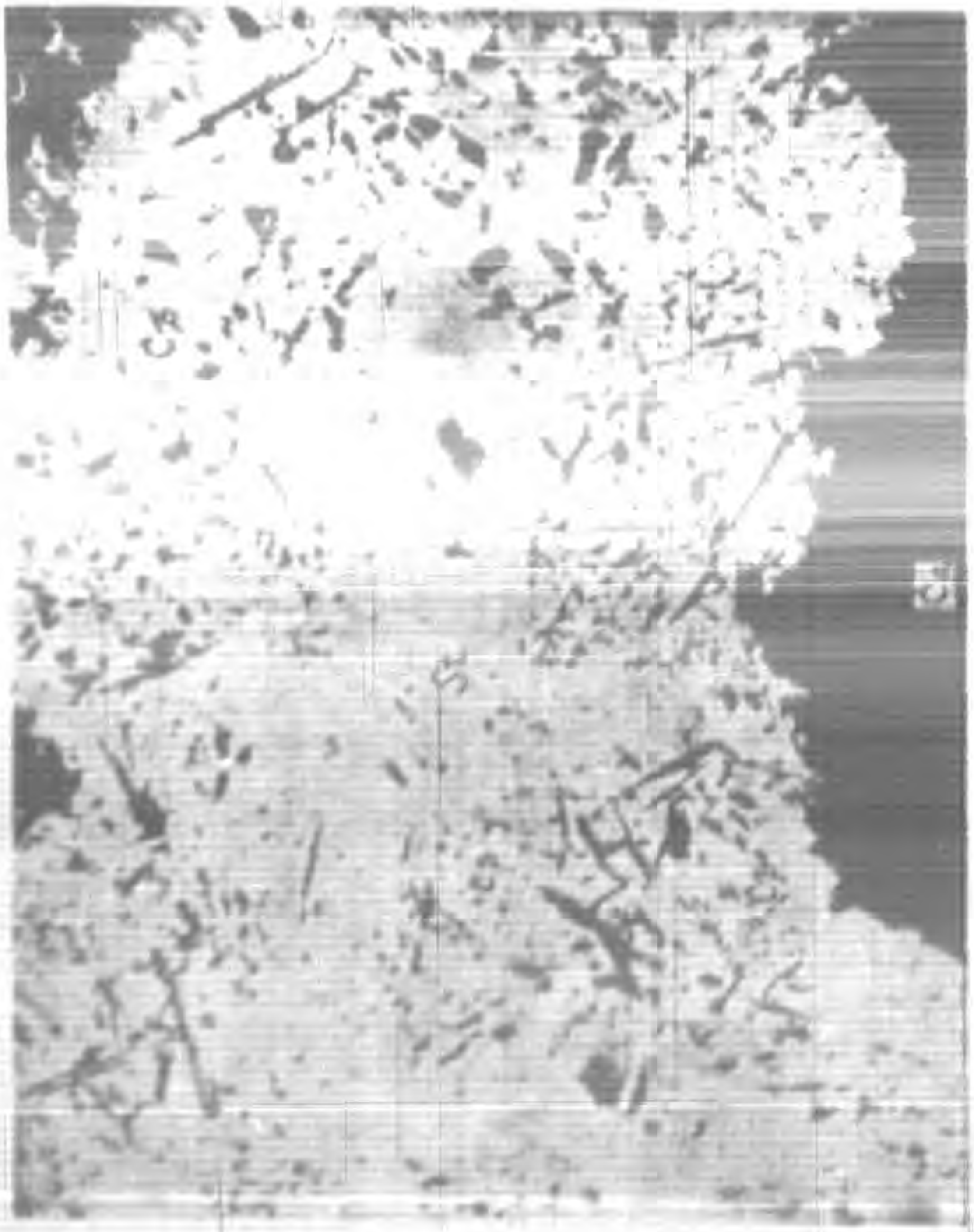

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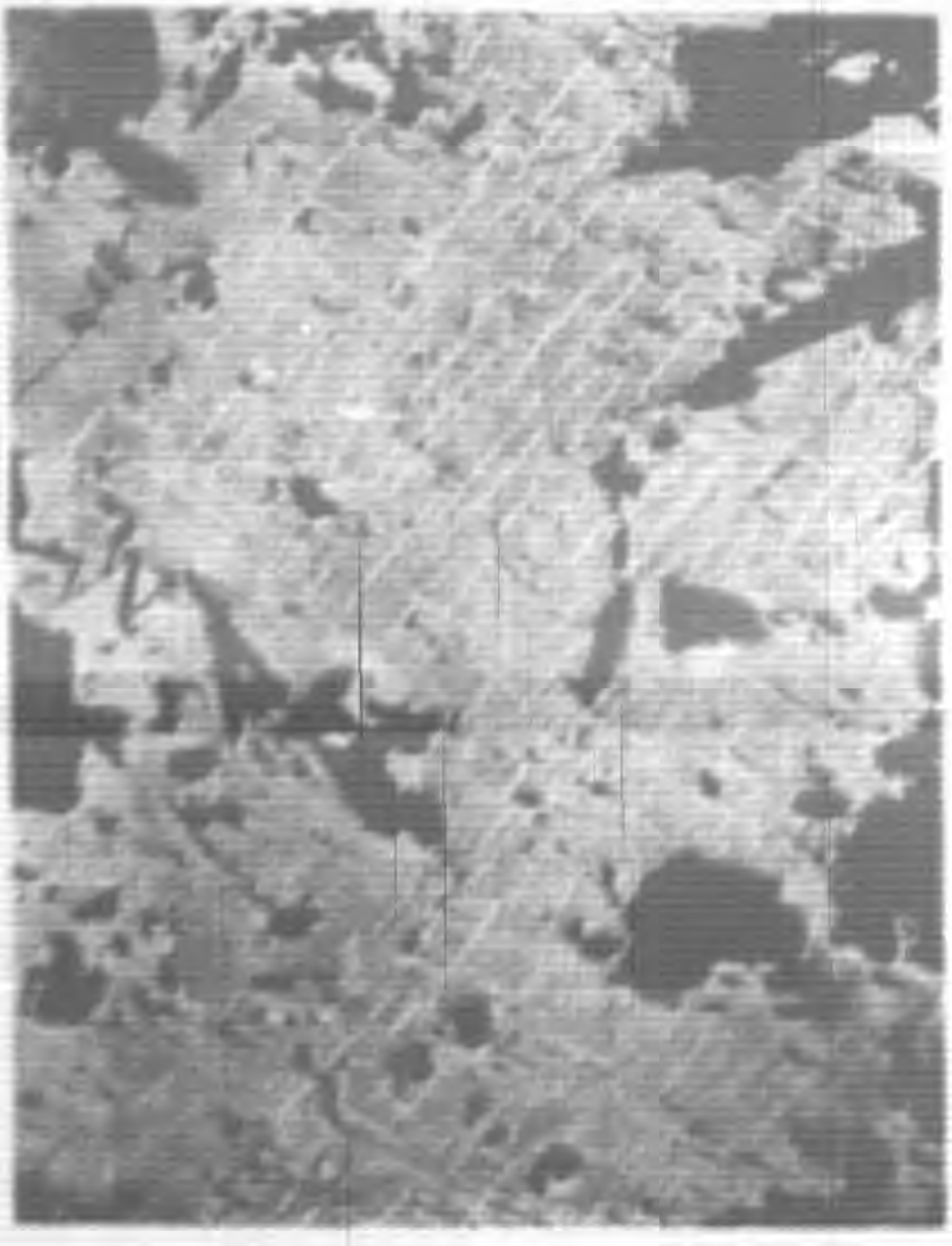

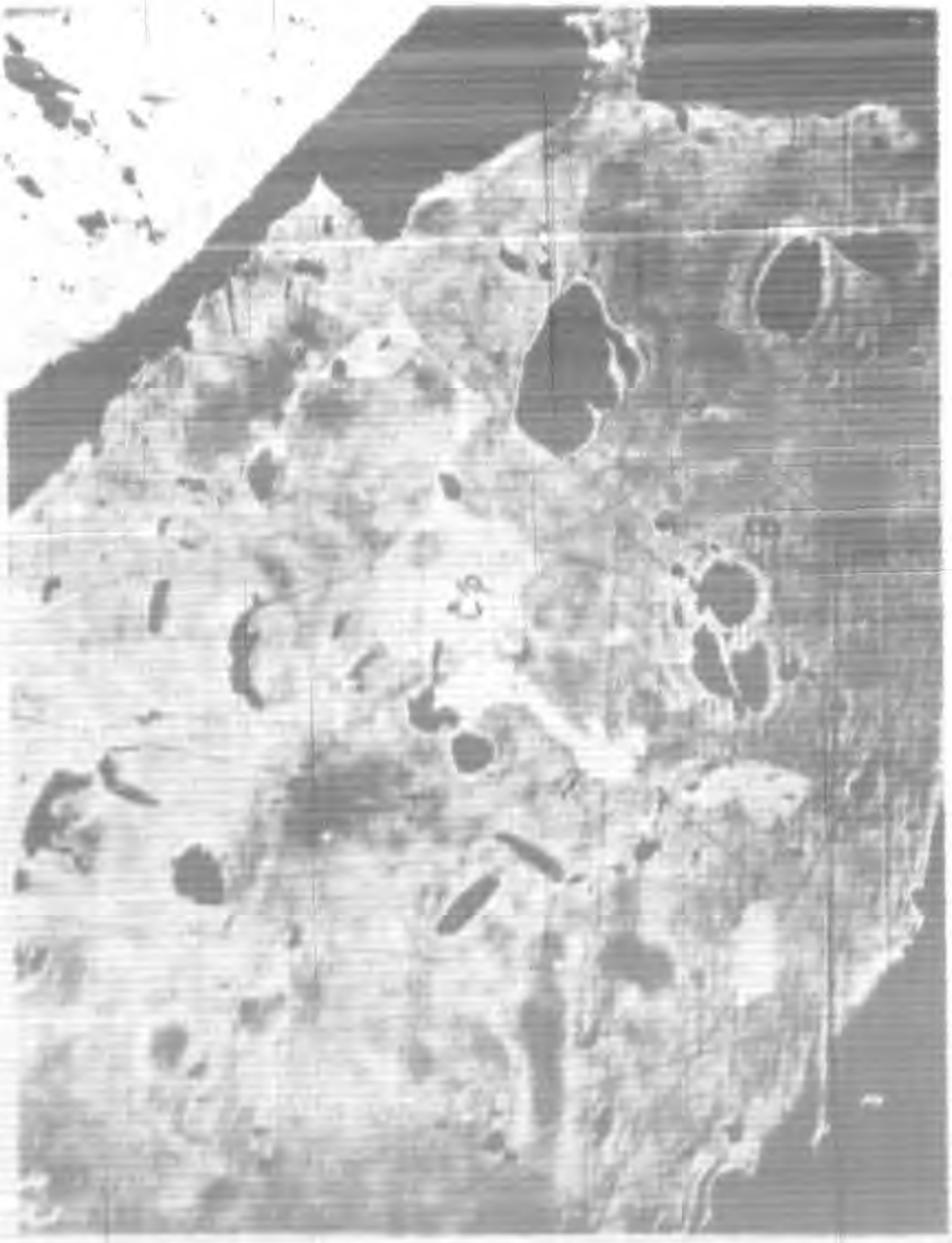

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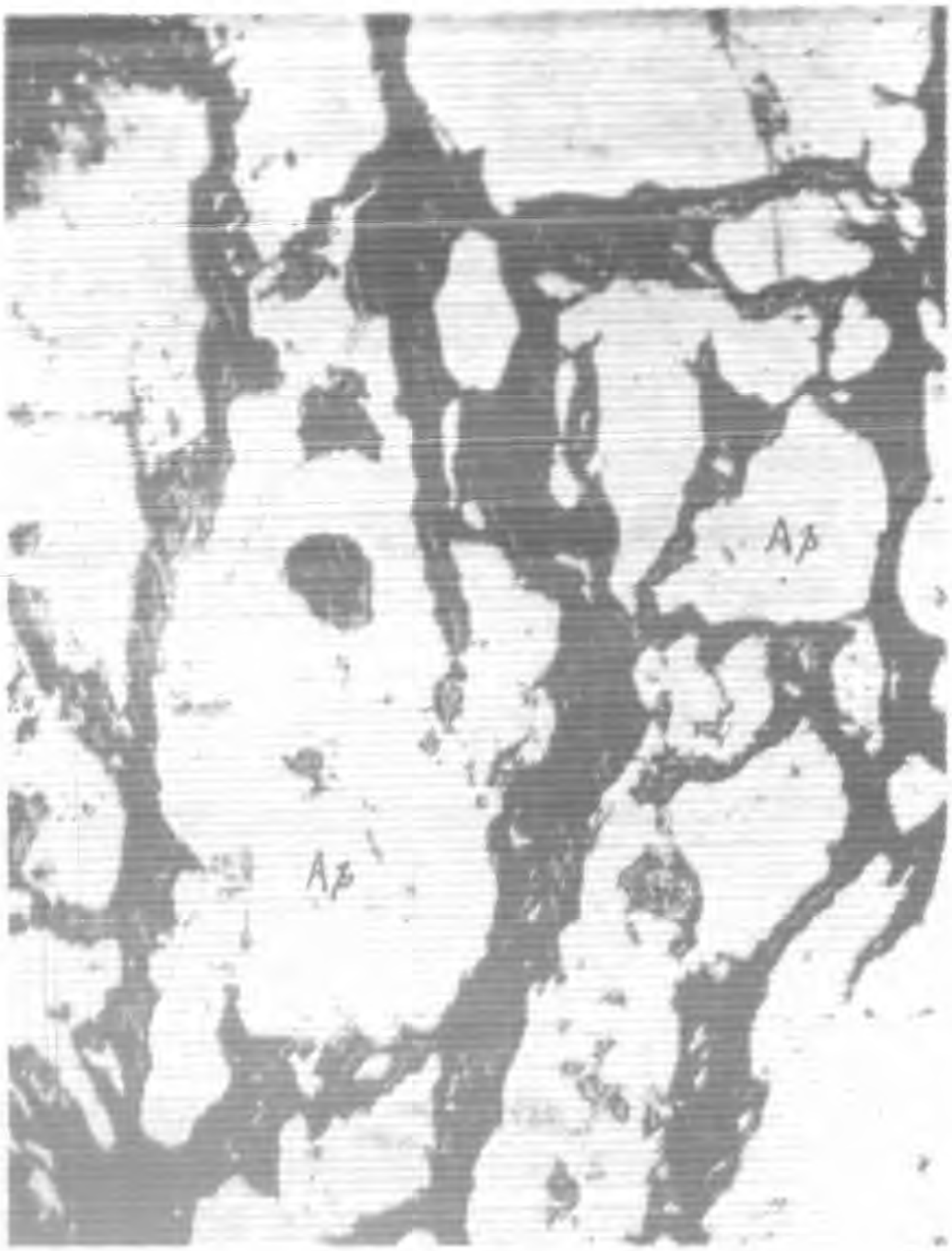

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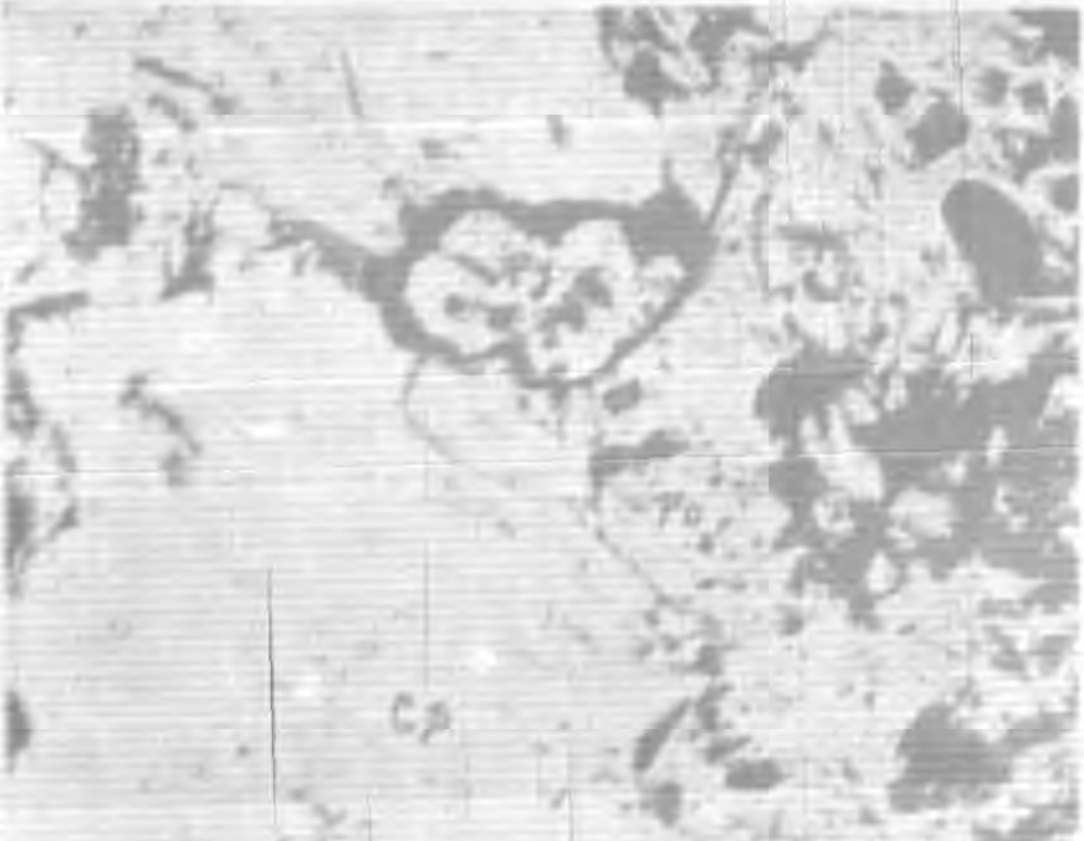

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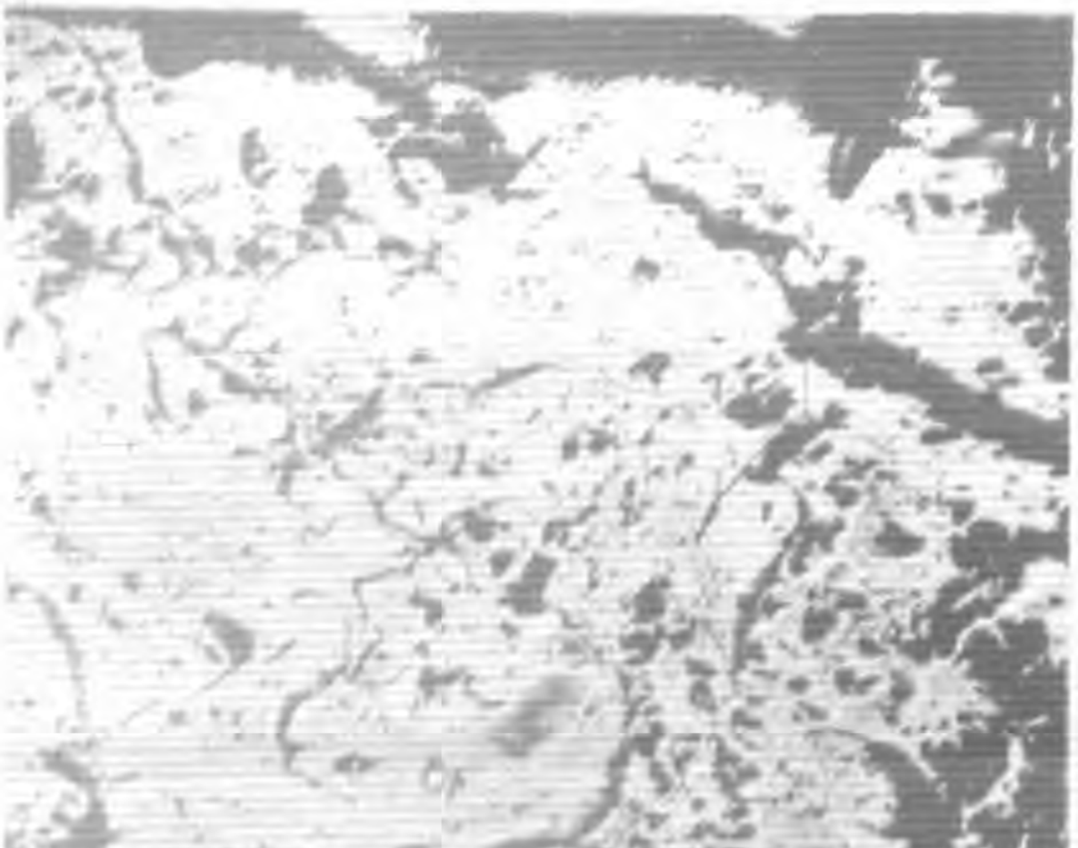

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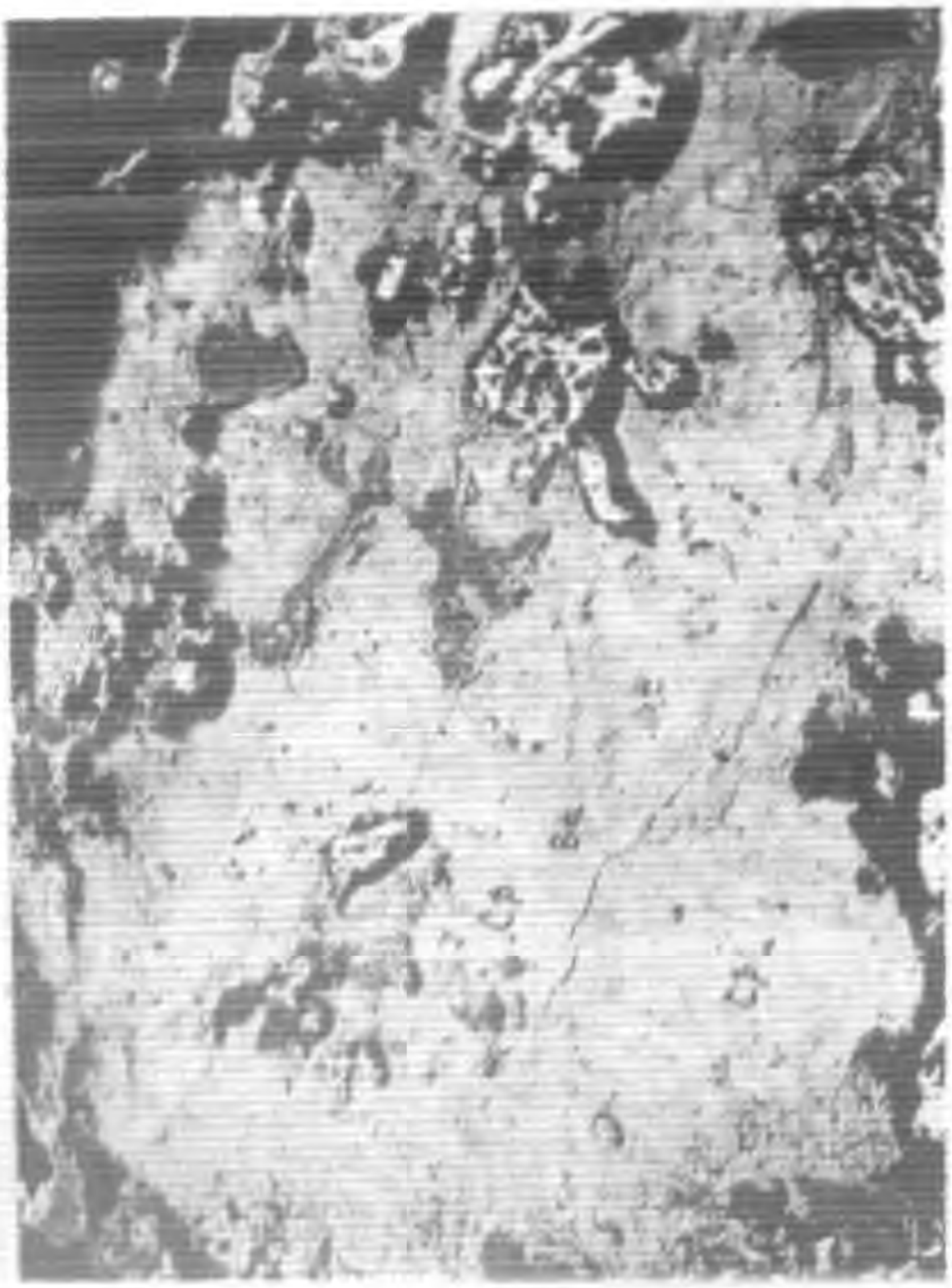

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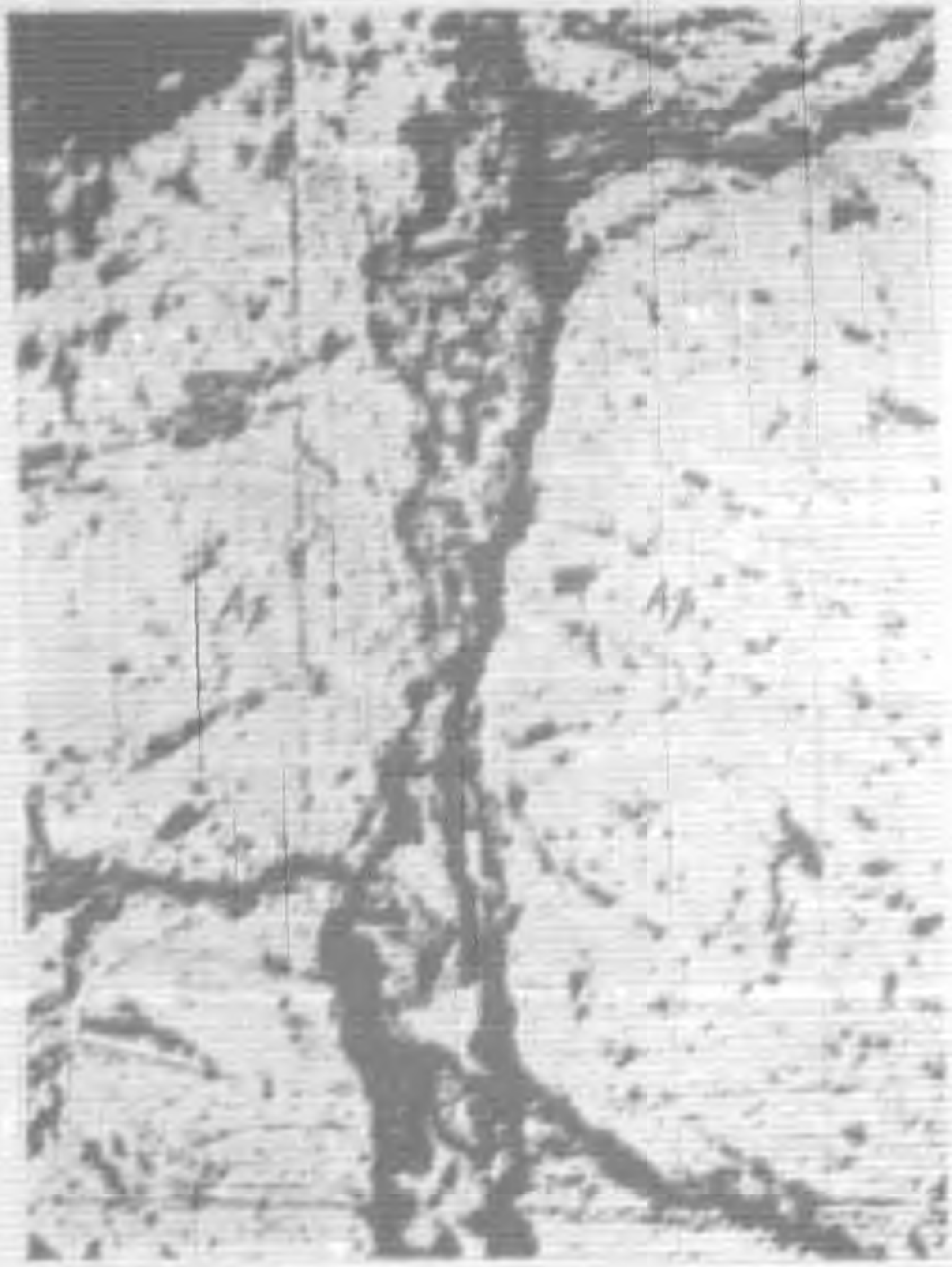

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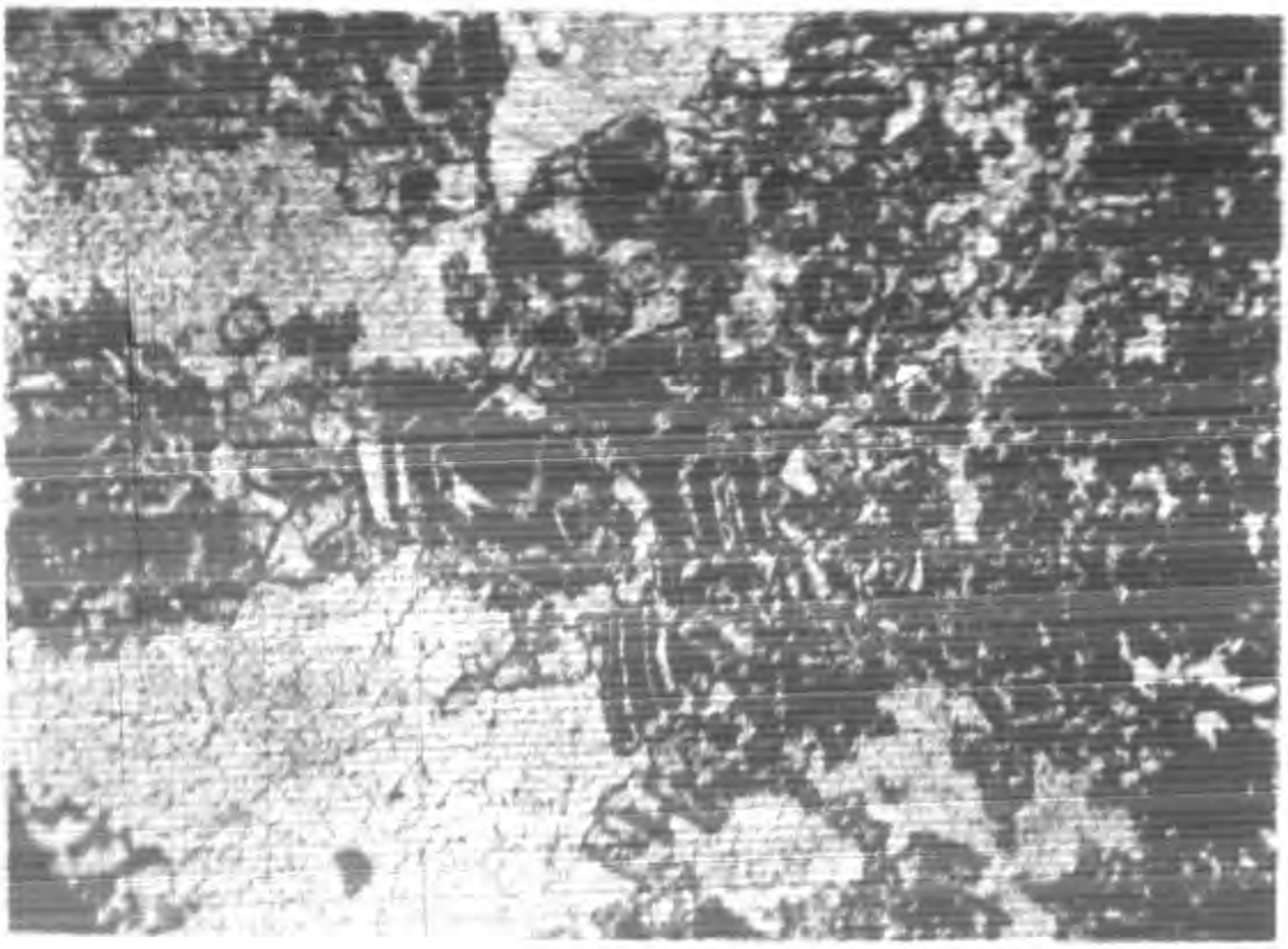

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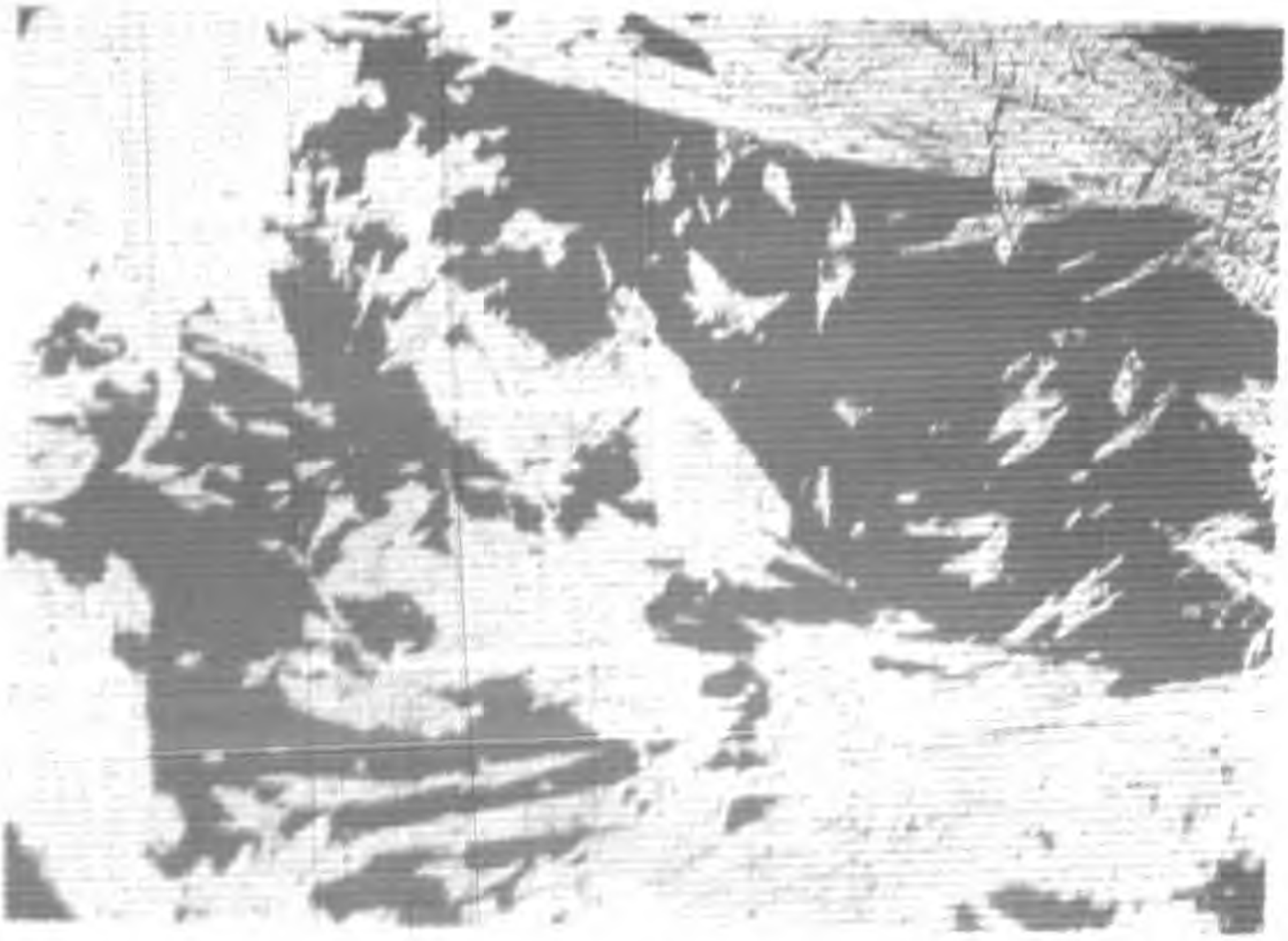

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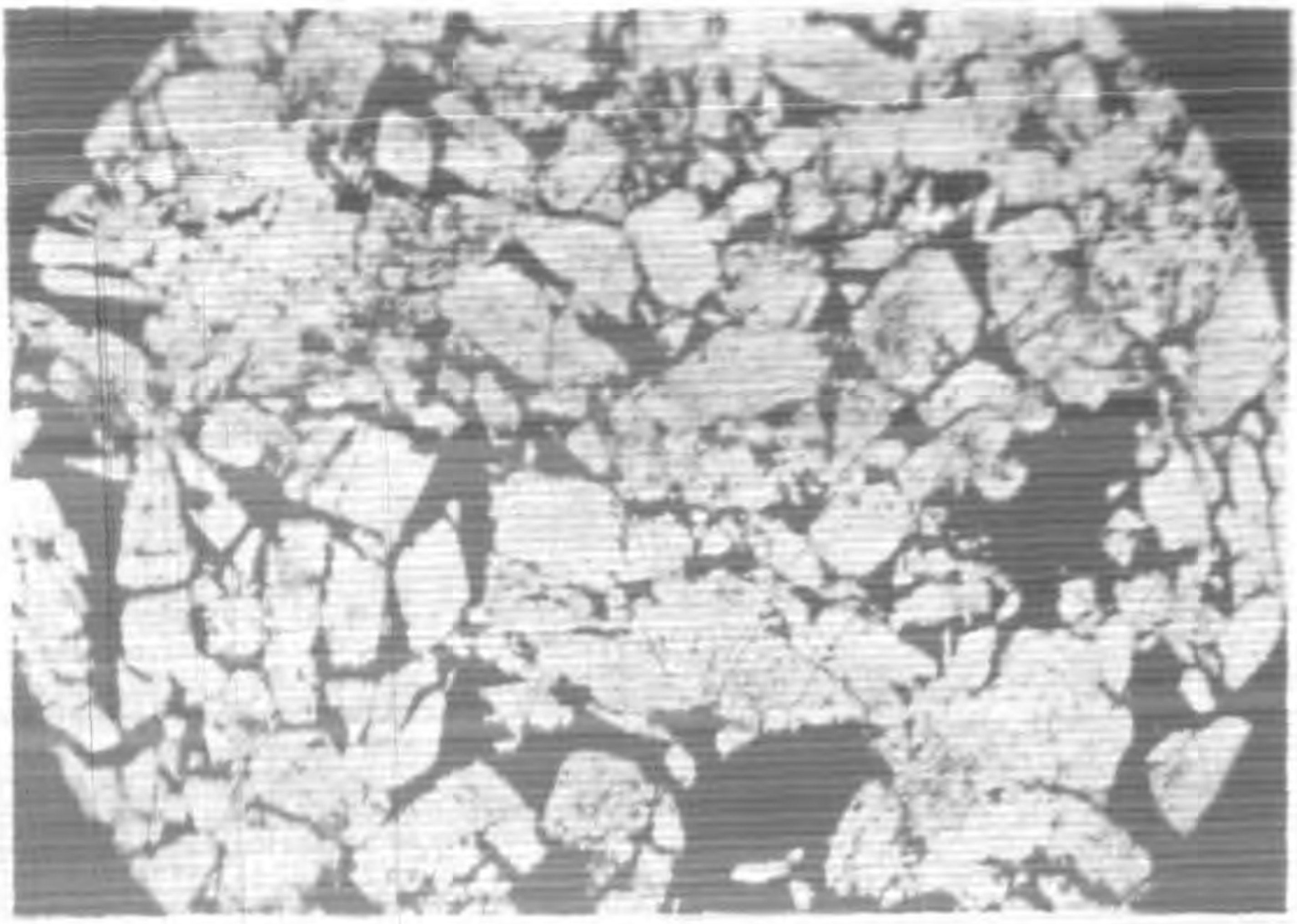

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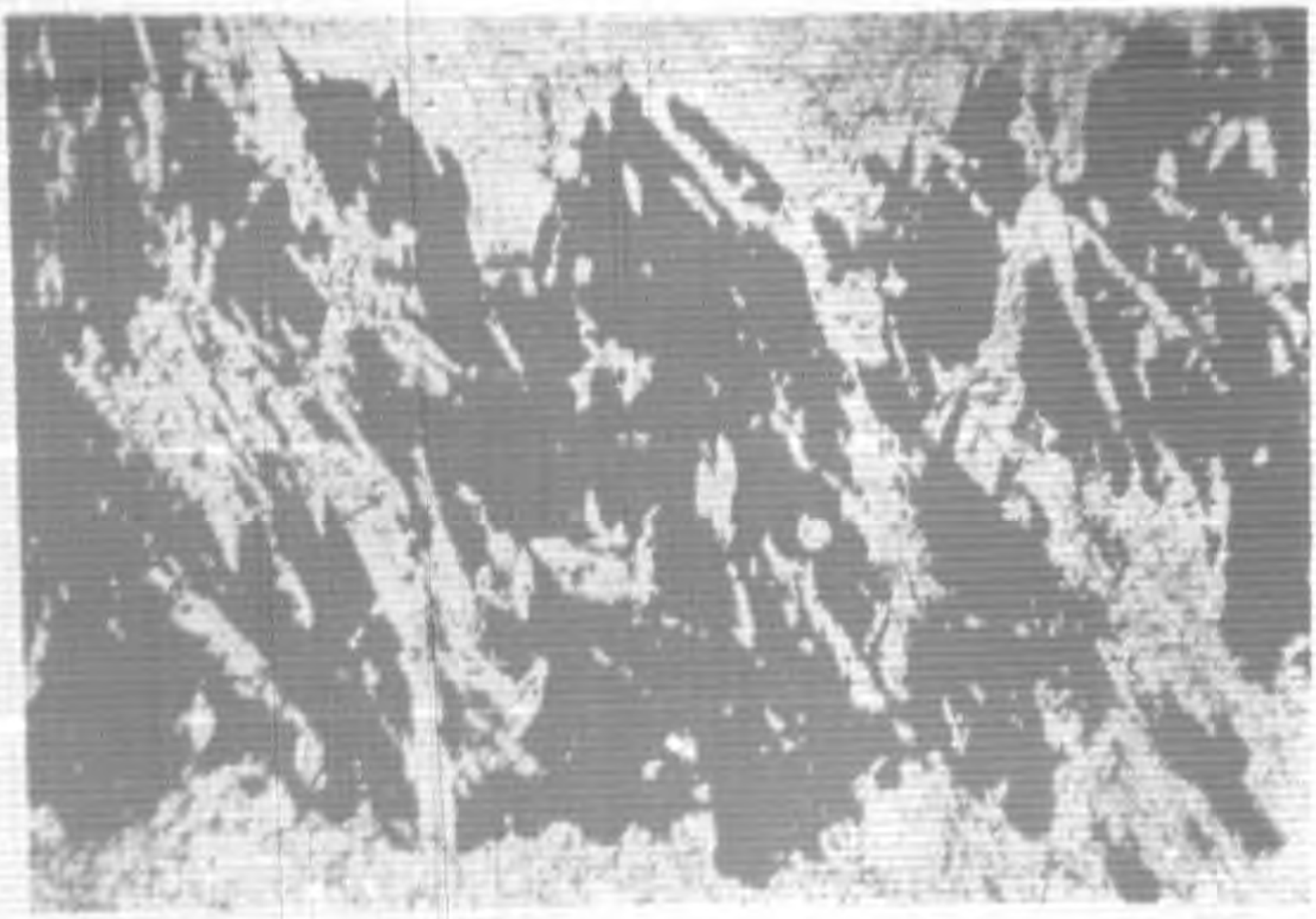

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