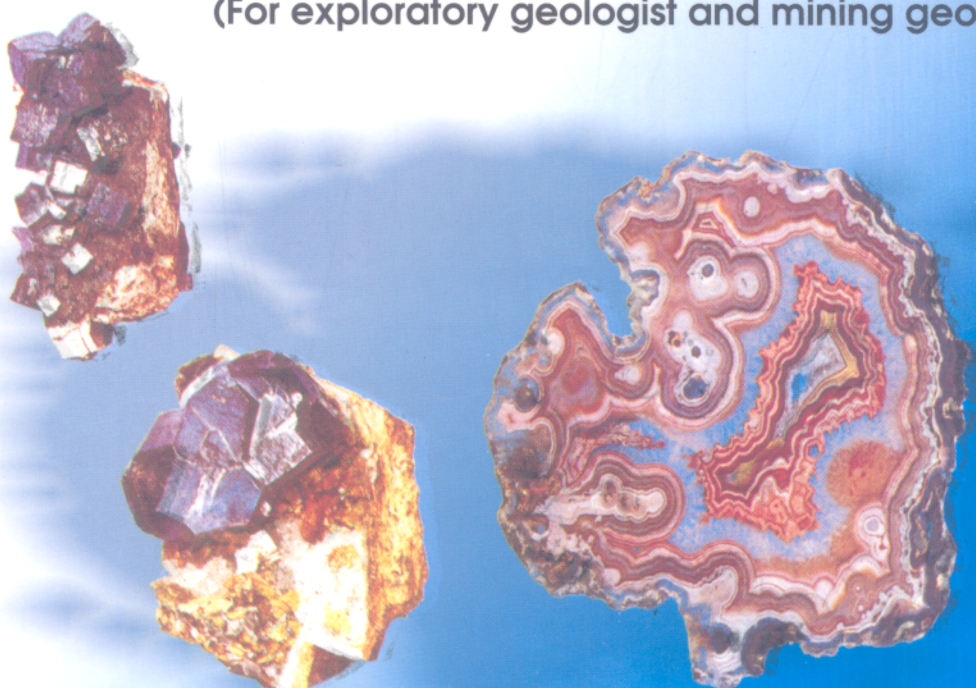
TRƯỜNG ĐẠI HỌC MỎ ĐỊA CHẤT
DOCTOR TRAN BINH CHU

# Tiếng Anh CHUYÊN NGÀNH ĐỊA CHẤT

(Dùng cho sinh viên ngành địa chất và địa chất mỏ)

# Special ENGLISH

(For exploratory geologist and mining geologist)



NHÀ XUẤT BẢN KHOA HỌC VÀ KỸ THUẬT

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NHÀ XUẤT BẢN KHOA HỌC VÀ KỸ THUẬT

HÀ NỘI

# TIẾNG ANH CHUYÊN NGÀNH ĐỊA CHẤT

**(Dùng cho sinh viên ngành địa chất và địa chất mỏ)**

**Tác giả: TRẦN BỈNH CHƯ**

| | |
|---|---|
| *Chịu trách nhiệm xuất bản:* | PGS. TS. TÔ ĐĂNG HẢI |
| *Biên tập và sửa bài:* | ThS. NGUYỄN HUY TIẾN |
| | NGỌC DIỆP |
| *Trình bày bìa:* | HƯƠNG LAN |

**NHÀ XUẤT BẢN KHOA HỌC VÀ KỸ THUẬT**
**70 Trần Hưng Đạo - Hà Nội**

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In 500 cuốn, khổ 19 × 27 cm, tại Xưởng in NXB Văn hoá Dân tộc
Quyết định xuất bản số: 75–2007/CXB/405/02/KHKT–6/2/2007
In xong và nộp lưu chiểu quý I năm 2007.

# LỜI TỰA

Trong những năm gần đây, tiếng Anh ngày càng phổ biến trong mọi lĩnh vực của cuộc sống. Tiếng Anh giao tiếp, tiếng Anh thương mại và tiếng Anh trong tin học được quan tâm nhiều nhất ở mọi nơi, mọi giới. Người cán bộ địa chất không những đòi hỏi kiến thức chuyên môn giỏi mà còn phải biết tham khảo tài liệu chuyên môn bằng tiếng Anh. Chính vì vậy, giáo trình Tiếng Anh chuyên ngành ra đời nhằm đáp ứng nhu cầu đó.

**"Tiếng Anh chuyên ngành địa chất"** của tác giả Trần Bỉnh Chư, cán bộ giảng dạy thuộc Bộ môn Khoáng sản, Khoa Địa chất, Trường Đại học Mỏ - Địa chất biên soạn, dựa trên kiến thức đã được tích luỹ nhiều năm trong ngành địa chất và đã trải qua các khoá đào tạo đại học và sau đại học ở nước ngoài. Tác giả đã từng học các giáo trình chuyên ngành địa chất thăm dò bằng tiếng Anh tại Học viện Địa chất và Viễn thám Quốc tế ở Hà Lan.

**"Tiếng Anh chuyên ngành địa chất"** giới thiệu với độc giả những vấn đề cơ bản về địa chất đại cương, các quá trình tạo khoáng nội sinh, ngoại sinh và biến chất sinh cũng như mô tả một số mỏ trên thế giới. Các khái niệm về mỏ khoáng, thăm dò, phát triển mỏ và tài nguyên - trữ lượng cũng được đề cập một cách cô đọng. Cuối mỗi bài được cung cấp một khối lượng lớn từ mới và từ vựng cần thiết nhằm giúp người đọc hiểu vấn đề. Giáo trình này làm tài liệu giảng dạy và học tập đối với sinh viên ngành địa chất thuộc Trường Đại học Mỏ - Địa chất.

Hy vọng rằng cuốn sách nhỏ sẽ có tác dụng không những đối với sinh viên ngành địa chất mà còn đối với những ai quan tâm đến lĩnh vực tiếng Anh trong địa chất, đặc biệt là các nhà địa chất đo vẽ bản đồ, tìm kiếm và thăm dò tài nguyên khoáng sản.

Xin trân trọng giới thiệu với bạn đọc cuốn **"Tiếng Anh chuyên ngành địa chất"** của TS. GVC. Trần Bỉnh Chư.

*Hà Nội, ngày 25 tháng 10 năm 2006*

**Trưởng Bộ môn Địa chất, Trường Đại học Mỏ - Địa chất**

***GS. TSKH. NGƯT. Đặng Văn Bát***

# LỜI NÓI ĐẦU

Lần đầu tiên, **TIẾNG ANH CHUYÊN NGÀNH ĐỊA CHẤT** được tác giả biên soạn và giảng dạy vào năm 2000 cho sinh viên khoá K42 ngành địa chất của Trường đại học Mỏ - Địa chất tại Hà Nội và Vũng Tàu. Từ đó đến nay, **TIẾNG ANH CHUYÊN NGÀNH ĐỊA CHẤT** được đưa vào chương trình chính khoá với 3 học trình (45 tiết) cho sinh viên năm thứ tư, thuộc ngành địa chất. Tuy còn một số thiếu sót, đặc biệt là lỗi chính tả, nhưng giáo trình cấp trường **TIẾNG ANH CHUYÊN NGÀNH ĐỊA CHẤT** đã cung cấp cho sinh viên một khối lượng từ vựng rất lớn - thuật ngữ chuyên môn về địa chất đại cương và các quá trình tạo khoáng nội sinh, ngoại sinh, biến chất cũng như tìm kiếm - thăm dò các mỏ khoáng sản.

Nhằm đáp ứng nhu cầu học tập của sinh viên, cán bộ và những người làm công tác địa chất, chúng tôi cho xuất bản giáo trình **TIẾNG ANH CHUYÊN NGÀNH ĐỊA CHẤT.** Giáo trình này được biên soạn trên cơ sở Giáo trình cấp trường năm 2000 có chỉnh lý, bổ sung và cập nhật một số tư liệu về tài nguyên - trữ lượng và khoáng sản Việt Nam; đặc biệt là các hình vẽ minh hoạ cũng được chú ý đúng mức.

Giáo trình **TIẾNG ANH CHUYÊN NGÀNH ĐỊA CHẤT** gồm ba phần: Phần đại cương, phần chuyên đề và phần mô tả các mỏ. Mỗi phần gồm một số bài, có khi cùng một nội dung nhưng được các tác giả khác nhau trình bày vẫn được đưa vào nhằm giúp cho sinh viên học được cách thể hiện ngữ pháp tiếng Anh. Cuối mỗi bài hoặc mỗi phần, tác giả đưa ra một số từ mới và tổ hợp từ hoặc thành ngữ để sinh viên và người đọc có thể hiểu được nội dung bài khoá.

Hy vọng rằng giáo trình **TIẾNG ANH CHUYÊN NGÀNH ĐỊA CHẤT** không những được dùng làm tài liệu giảng dạy chính thức cho sinh viên mà còn bổ ích cho những ai quan tâm đến lĩnh vực tiếng Anh trong địa chất, nhất là tài nguyên khoáng sản, cũng như tìm kiếm thăm dò. Chắc chắn không tránh khỏi một số khiếm khuyết nhất định, vì vậy tác giả xin chân thành cảm ơn sự đóng góp của độc giả gần xa về hình thức và nội dung của giáo trình. Mọi sự góp ý, phê bình xin gửi theo địa chỉ: Bộ môn Khoáng sản, Khoa Địa chất, Trường Đại học Mỏ - Địa chất, Đông Ngạc, Từ Liêm, Hà Nội.

Hà Nội, ngày 25 tháng 4 năm 2006.

***Tác giả Trần Bỉnh Chư***

# PART ONE: GENERAL GEOLOGY

## CHAPTER ONE: MAJOR GENERAL INFORMATION

### I.1. WHAT IS GEOLOGY?

Geology is the study of the planet Earth - The materials of which it is made, the processes that act on these materials, the products formed and the history of the planet and its life forms since its origin. Geology considers the physical forces that act on the Earth, chemistry of its constituent materials, and the biology of its past inhabitance as revealed by fossils. Clues on the origin of the planet are sought in a study of the Moon and other extraterrestrial bodies - the knowledge thus obtained is placed in the service of man to aid in discovery of mineral of value in the Earth crust.

### I.2. MINERALS AND CRYSTALS

**a) Minerals**

The rocks which form the Earth, the Moon and the planets are made up minerals. Minerals are solid substances composed of atoms having an orderly and regular arrangement. This orderly atomic arrangement is the criterion of crystalline state and it means also that it is possible to express the composition of a mineral as a chemical formular (Figures 1 to 5).

**b) Crystals**

When minerals are free to grow without constrain, they are bounded by crystal faces which are invariably disposed in a regular way such that there is a particular relationship between them in any one mineral species. A crystal is bounded by naturally formed plane faces, and its regular outward shape is an expression of its regular atomic arrangement.

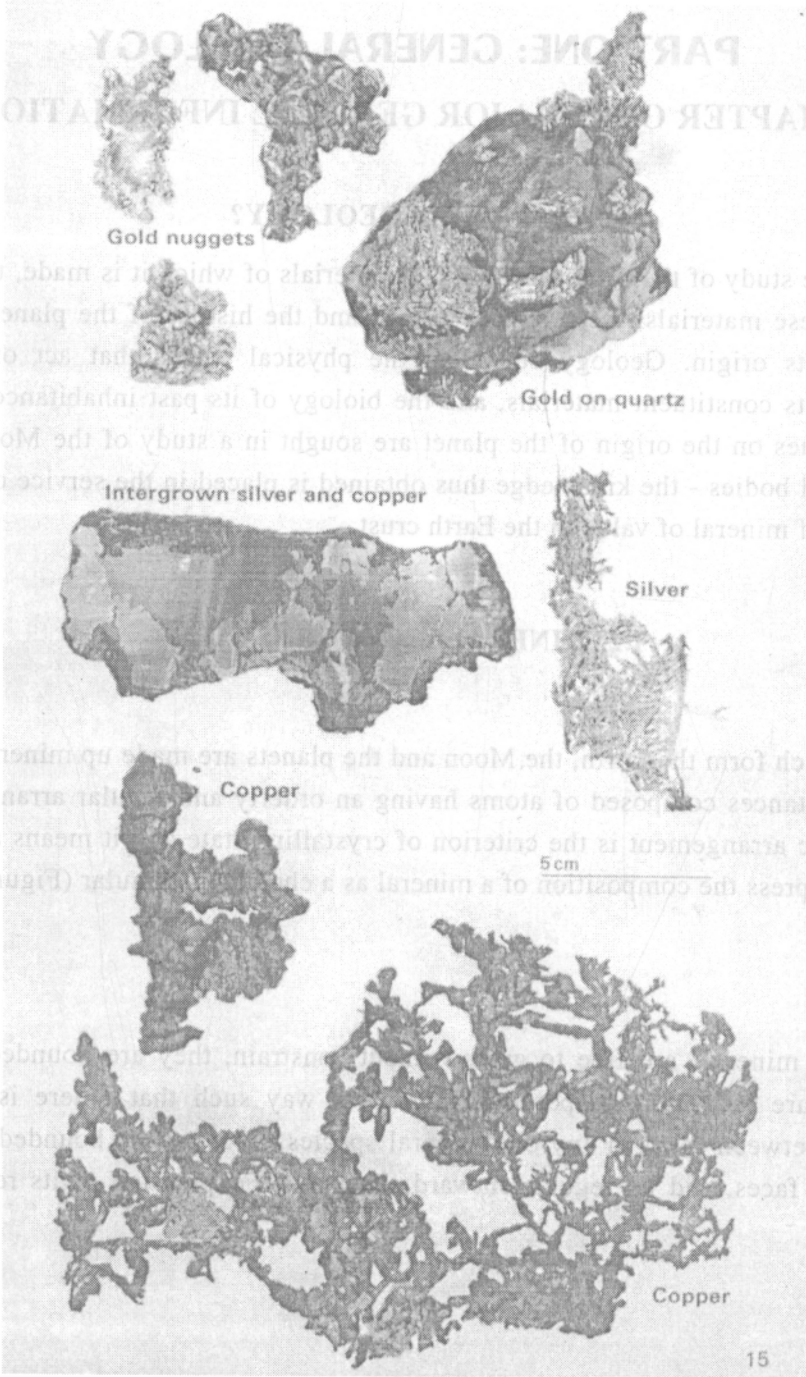



**Figure 1.** Native elements: gold, silver and cupper.

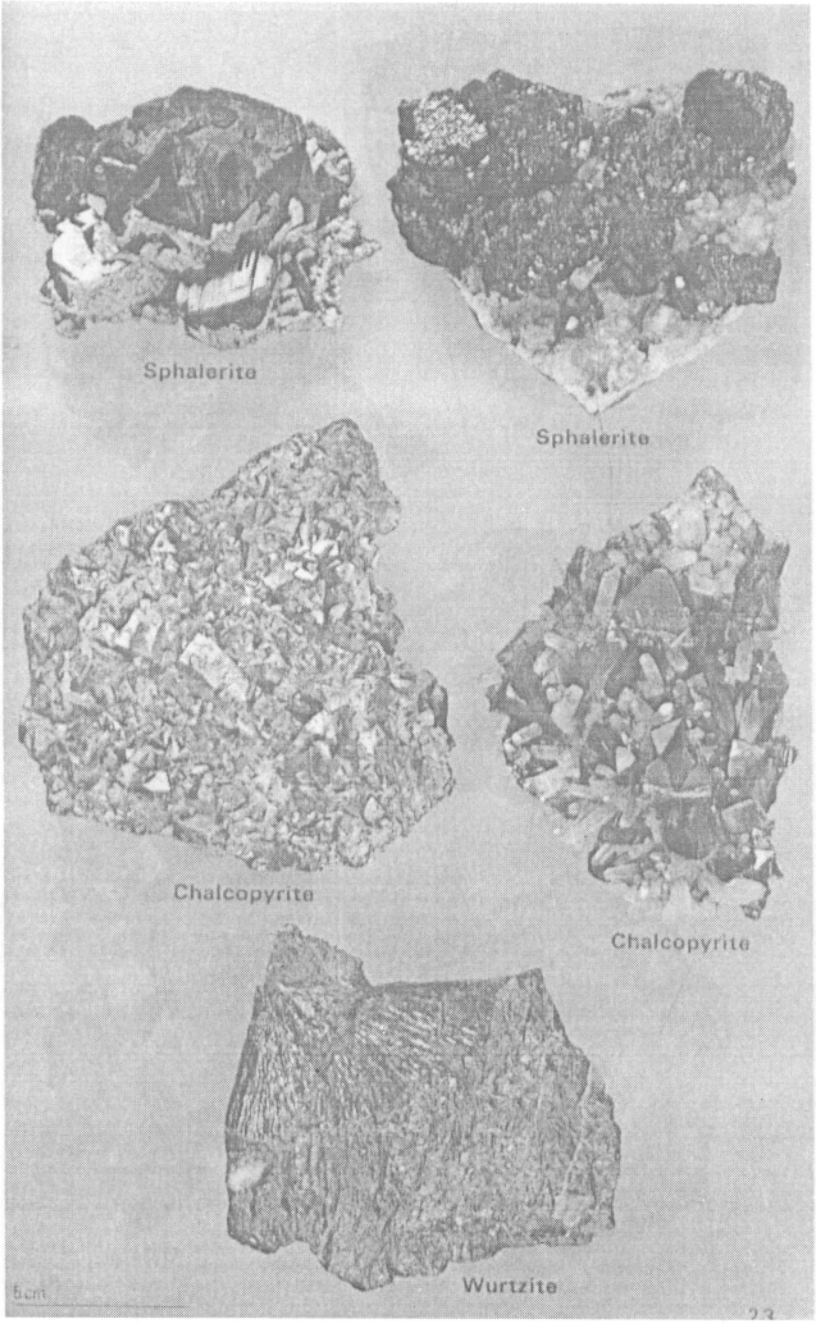



**Figure 2.** Minerals: chalcopyrite, sphalerite, wurtzite.

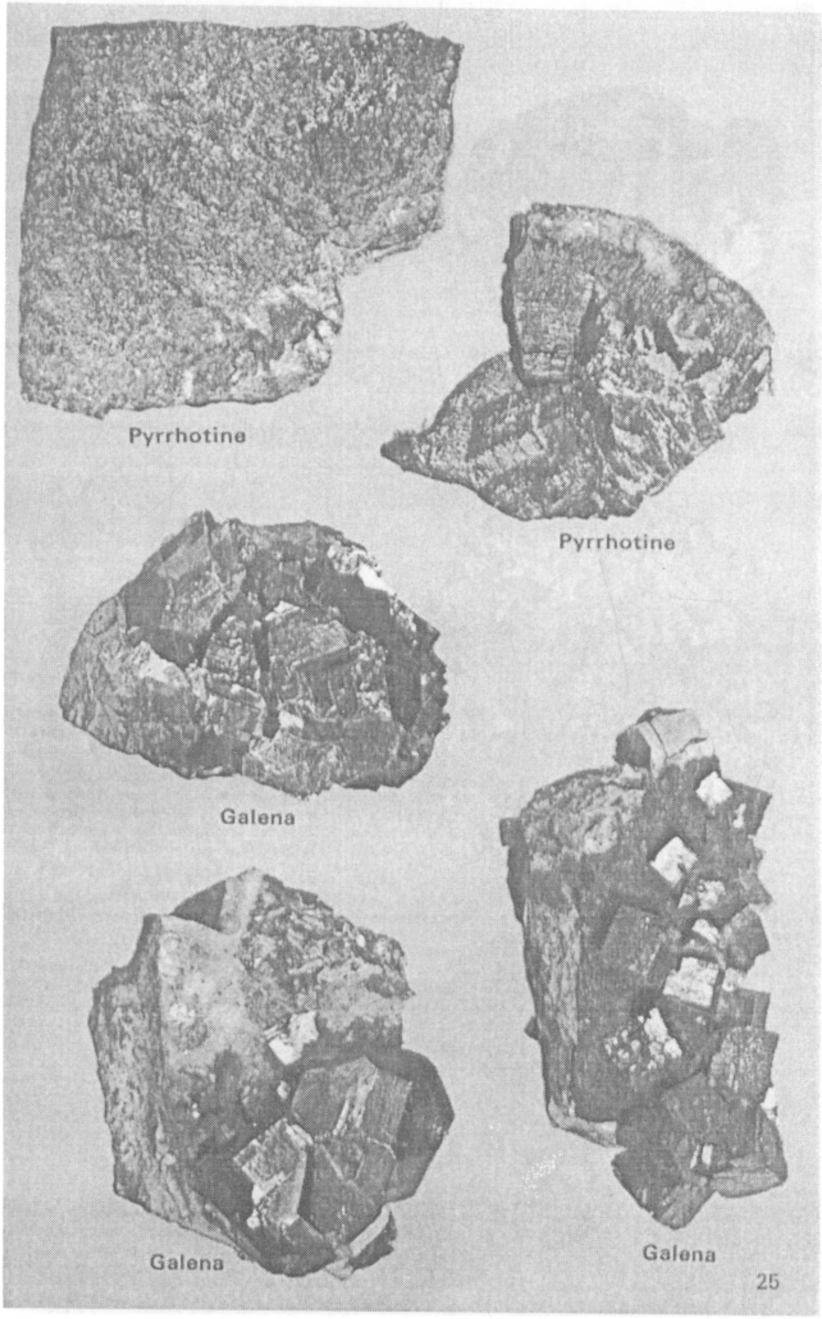



**Figure 3.** Minerals: galena/galenite, pyrrhotine.

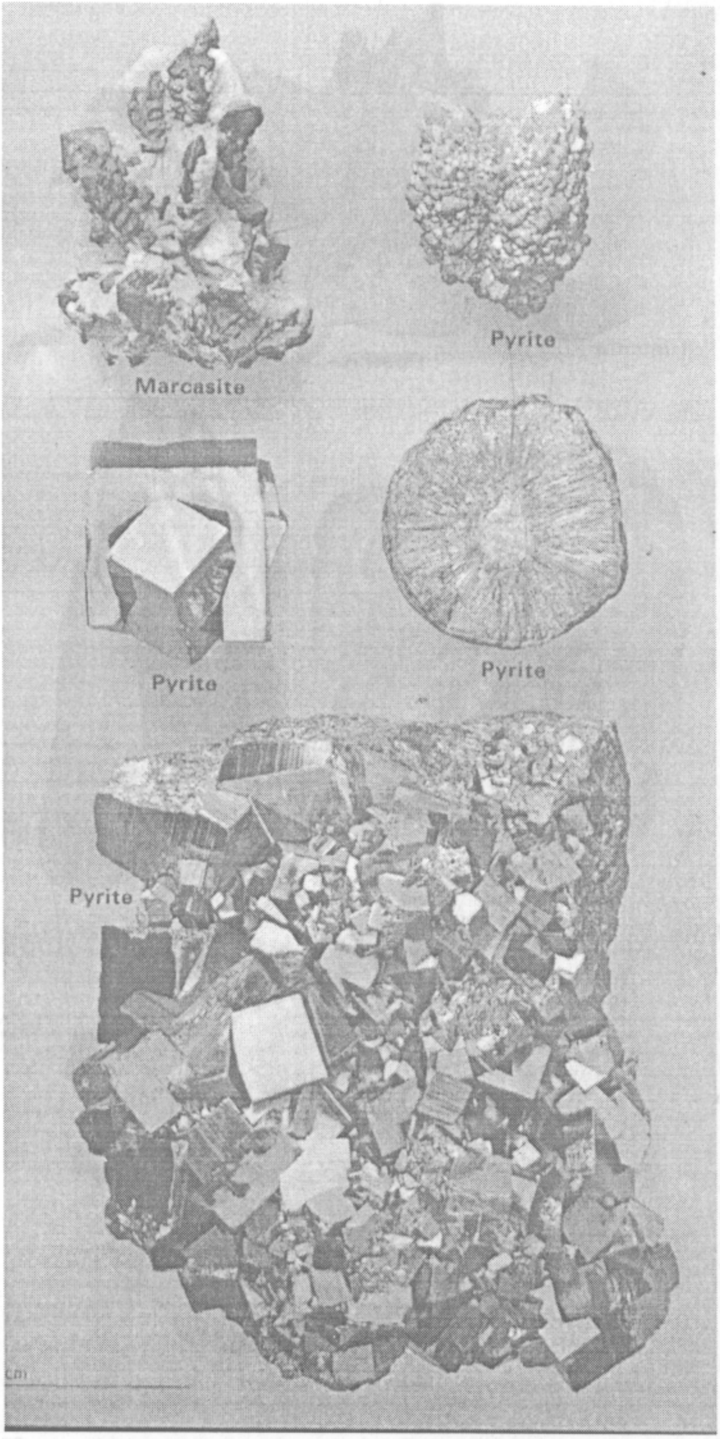



**Figure 4.** Minerals: marcasite, pyrite.

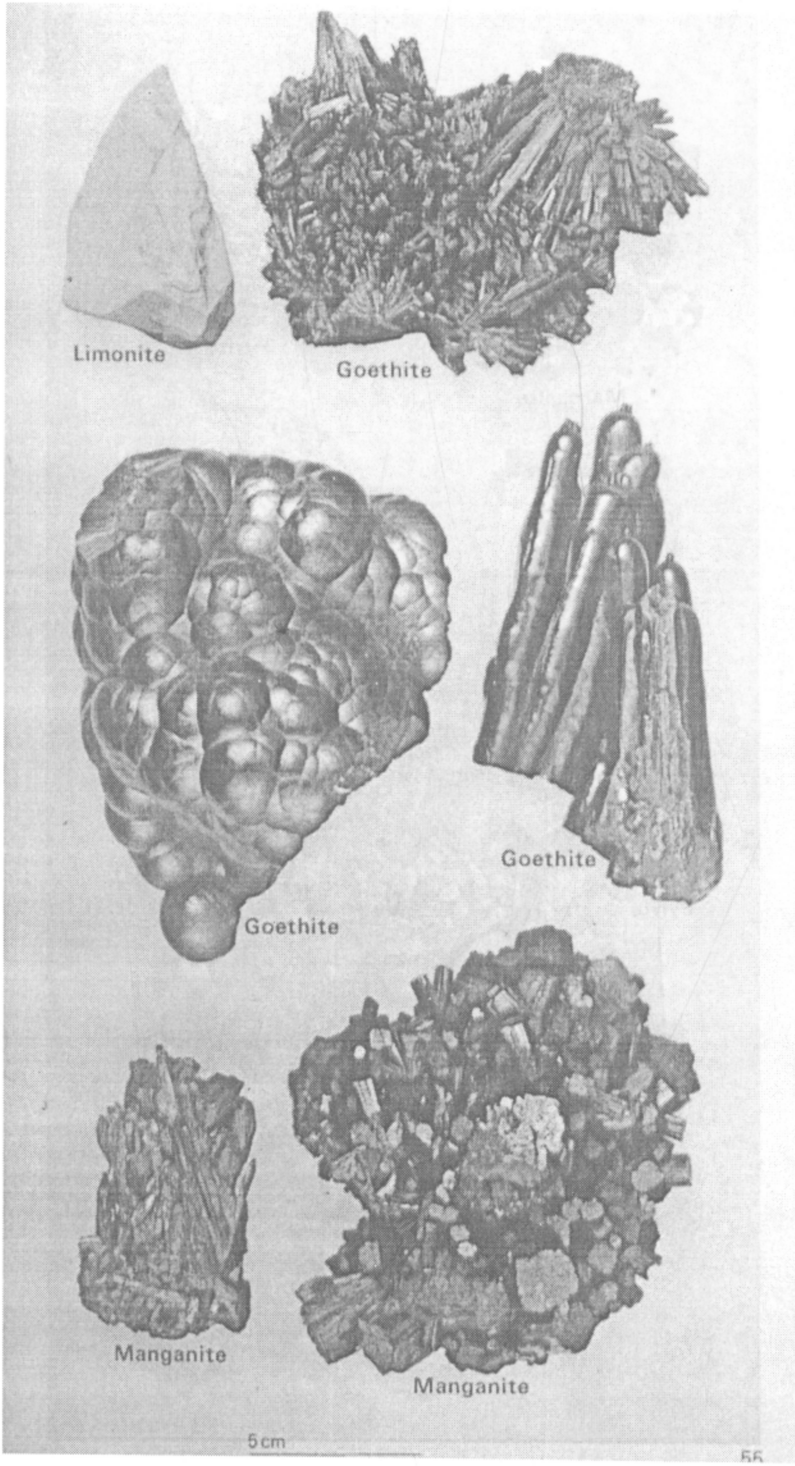



Figure 5. Goethite, manganite.

## I.3. MINERALS AGGREGATES

Most minerals occur as aggregates of crystals that rarely show perfect crystal shapes. The form of the aggregate, however, can be useful in identification. The resulting form resembles a bunch of grapes is called *botryoidal*. The larger and more gently rounded shapes are said to be *mamillated*. Native copper and gold often form distinctive branching and divergent forms to which the term *dendritic* is applied. Crystals form distinctly flat sheets are said to be the *lamellar*. If the lamellar are very thin and can be readily separated, like the pages of a book, they are said to be *foliated*. These and other examples are given in the mineral description

## I.4. ROCKS

The Earth, the Moon and the planets are build of the material we call rock. The solid stuff of mountains, the loose sand gravel of beaches and deserts are all rocks. Rocks are aggregates of minerals, but the petrologists, as well as being interested in the mineralogy of rock, also tries to unravel the record of the geological past which they contain. It is from reading the 'record of the rocks' that so much has been learned about past climates and geography, and about the past and present composition of, and the conditions which prevain within the interior of our planet.

Rock can be conveniently grouped into ***igneous rocks, metamorphic rocks and sedimentary rocks***. Igneous rocks are formed by the solidification of molten rock material; metamorphic rocks are formed through the alteration of igneous and sedimentary rocks; while sedimentary rocks are produced by the accumulation of rock waste at the Earth's surface

## VOCABULARY

| | |
|---|---|
| Revealed by fossils | Được phát hiện bằng hoá thạch |
| Are sought | Được tìm |
| Past inhabitance | Đã sống/đã tồn tại |
| Extraterrestrial bodies | Thiên thể/các vật thể ngoài vũ trụ |
| Grow without constrain | Phát triển tự do |
| Crystalline state | Trạng thái tinh thể |
| Crystal faces | Mặt tinh thể |
| Unravealed (adj) | Không được phát hiện |
| Is bounded | Được giới hạn |

| | |
|---|---|
| Petrologists | Các nhà thạch học |
| Mineral aggregate | Tập hợp khoáng vật |
| Solid substances | Các chất rắn |
| Lamellar (adj) | Dạng tấm |
| Dendritic (adj) | Dạng cành cây |
| Mamillated (adj) | Dạng vú |
| Botryoidal (adj) | Dạng thận |
| Foliated (adj) | Dạng phiến |
| To unravel | Làm sáng tỏ |
| Mineralogy | Khoáng vật học |
| 'Record of the rocks' | Di tích/ tài liệu của đá |
| Igneous rocks | Đá macma xâm nhập |
| Metamorphic rocks | Đá biến chất |
| Sedimentary rocks | Đá trầm tích |
| Accumulation | Sự tích tụ |

## I.5. WHAT IS EXPLORATION?

In North America the terms "Prospecting & Exploration" are interchangeable with "exploration", the preferred term for entire sequence of work ranging from reconnaissance (looking for a prospect) to the evaluation of the prospect and finally to the search for additional ore in a mine.

In Russian "Prospecting for mineral deposits" and "exploration" of mineral deposits that we explore the prospects after they have been found (Kreiter 1968, page 114)

In France and some other countries the meanings are just the opposite: "exploration" refers to a wide-ranging search for indication of mineralization, "prospecting" refers to a more localized study of the indication (Routhier, 1963 page1002)

## I.6. PRINCIPLE STEPS IN THE ESTABLISHMENT & OPERATION OF A MINE

1. Mineral exploration: To discover an ore-body.
2. Feasibility study: To prove its commercial viability.
3. Mine development: Establishment of the entire infrastructure.

4. Mining: Extraction of ore from the ground.

5. Ore dressing (mineral processing): Milling of the ore, separation of ore minerals from gangue, separation of the ore minerals into concentrates, separation & refinement of industrial mineral products.

6. Smelting: Recovering metals from the mineral concentrates.

7. Refining: Purifying the metal.

8. Marketing: Shipping the products to the buyer (Custom smelter, manufacturer).

## I.7. SPECIALISTIC TERMS

1. **Economic geology**: A study the geological aspects (including age, genesis, environment of formation, grade and grade distribution, tonnage, mineral paragenisis, geochemistry, etc...) of the mineral resources in this Earths crust.

2. **Mineral deposit**: A natural concentration of useful substances, which under favourable circumstances can be profitably extracted; or a rock building association from which under the prevailing technical and economic condition, one or more metals or compounds may be profitably extracted. *Or in other words*: the natural occurring material from which a mineral or minerals of economic value can be extracted.

3. **Mineralization**: (i) The process by which matter is introduced in to a rock resulting in the formation of new minerals of potentially economic value or of a mineral deposit; (ii) The state resulting from this process.

4. **Resource**: A natural concentration occurring solid, liquid, or gaseous materials in or on the Earths crust in such form that economic extraction of a commodity is currently or potentially feasible.

5. **Reserve**: That portion of the identified resource from which a usable mineral or energy commodity can be economically and legally extracted at the time of determination (Figure 6)

## VOCABULARY

| | |
|---|---|
| Prospecting & Exploration | Tìm kiếm và thăm dò |
| Reconnaissance | Khảo sát, điều tra |
| Evaluation | Đánh giá |
| Smelting | Luyện kim |
| Refining | Tinh chế, luyện tinh |
| Gangue mineral | Khoáng vật mạch, không quặng |

| | |
|---|---|
| Mineral deposit | Mỏ khoáng, mỏ khoáng sản |
| Profitably extracted | Khai thác có lãi |
| Mineral Resource | Tài nguyên khoáng sản |
| Mineral Reserve | Trữ lượng khoáng sản |
| Grade | Hàm lượng |
| Tonnage | Trọng lượng |
| Potentially economic value | Có giá trị kinh tế tiềm năng |

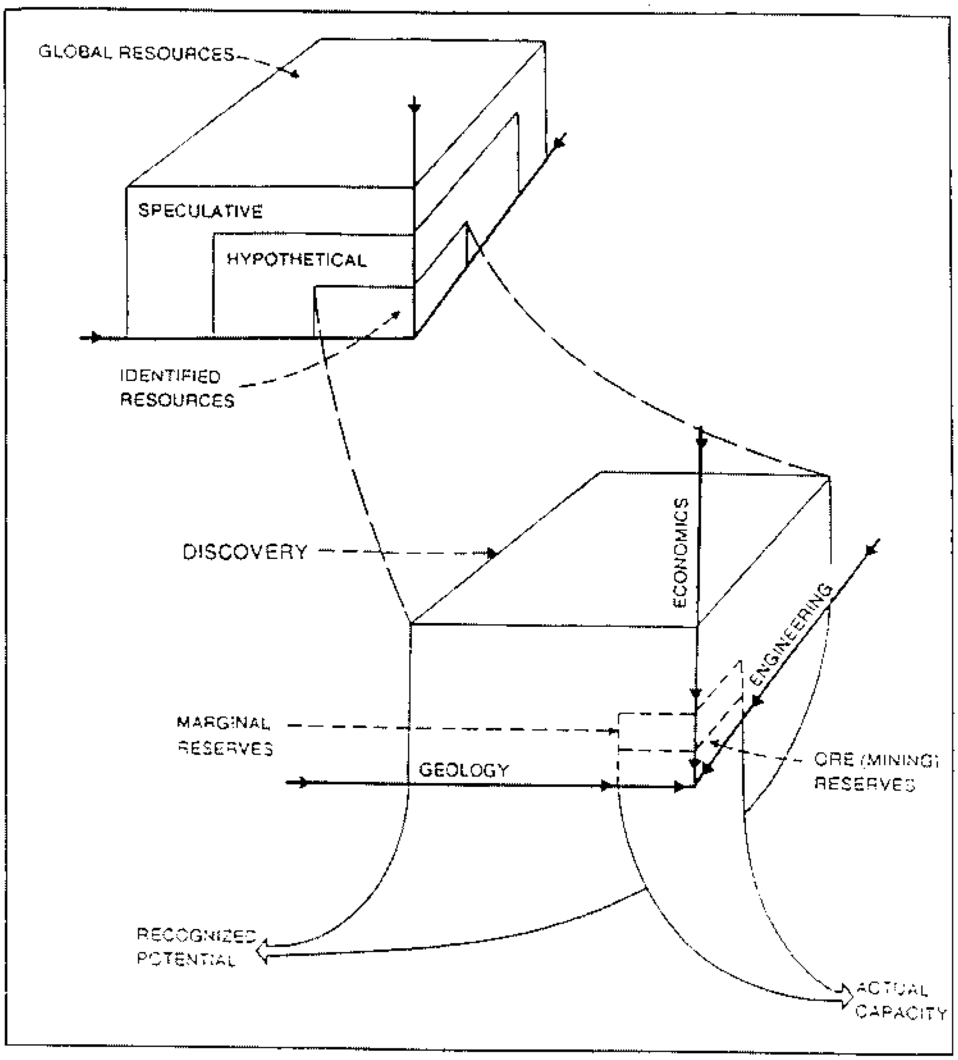



**Figure 6.** Evoluation of resources to reserves (Modified from Hughes et al. 1988, according to scheme proposed by Harrison 1983).

# CHAPTER TWO: GENERAL GEOLOGY

## II.1. GEOLOGICAL MAPS

Topographic maps primarily represent the form of the Earth's surface. Selected other features, both natural and artificial, may be included for information. Once one becomes accustomed to reading them, topographic maps can make excellent navigational aid.

Geological maps are one way of representing the underlying geology. The most common kind of geological map is a map of bedrock geology which shows the geology as it would appear with soil stripped away. From a well-prepared geological map, aspects of the subsurface structure can often be deducted. (But other maps may show distribution of different soil types, glacial deposits, or other features of surface geology).

Fundamental to making a geological map is identifying a suitable set of a map units. These may, for example be, individual sedimentary rock formations, distinguishable lava flows, or metamorphic rock units. The mapper then marks which of the map units are found at each place where the rocks are exposed.

Additional information, such as the orientation of beds or the location of contacts between map units, may also be recorded. Where obvious, contacts are drawn as solid lines; where only inferred, as dashed lines.

On a geological map, different units are represented in colors for clarity. Units of similar age may be shown in different shades of the same color. The map is accompanied by a key showing all the maps, arranged in chronological order, with the youngest at the top. Ordinarily, a brief description of each map unit is given; alternatively, standard patterns may be used to indicate the general rock type. Each unit is also assigned a symbol. The first part of the symbol consists of one or two letters corresponding to the unit's age – system (periotd). This is usually followed by one to three lowercase letters corresponding to the series (epoch).

Often, the marker of a geological map assists the map reader by supplying one or more geological cross sections. A cross section is a three-dimensional interpretation of the geology seen at the surface. The line along which the cross sections is drawn s indicated on the map. The cross section uses the same map units and symbols as the map proper and attempts to show the geometric relationships inferred to exist among those units- fauls, folds, intrusive relationships, and so on (Figures 7, 8, 9).

The cross section is drawn by starting with a topographic profile along the chosen line and marking on it the geology as seen from the surface. Depending on the complexity of the geology and the completeness of exposure on which the original geological map has been based, it may or may not be possible to develop a unique structural interpretation for the observed map pattern. If it is not, several plausible alternatives might be presented. Cross sections can be very valuable in evaluating site suitability for mineral exploration, construction and other purposes.

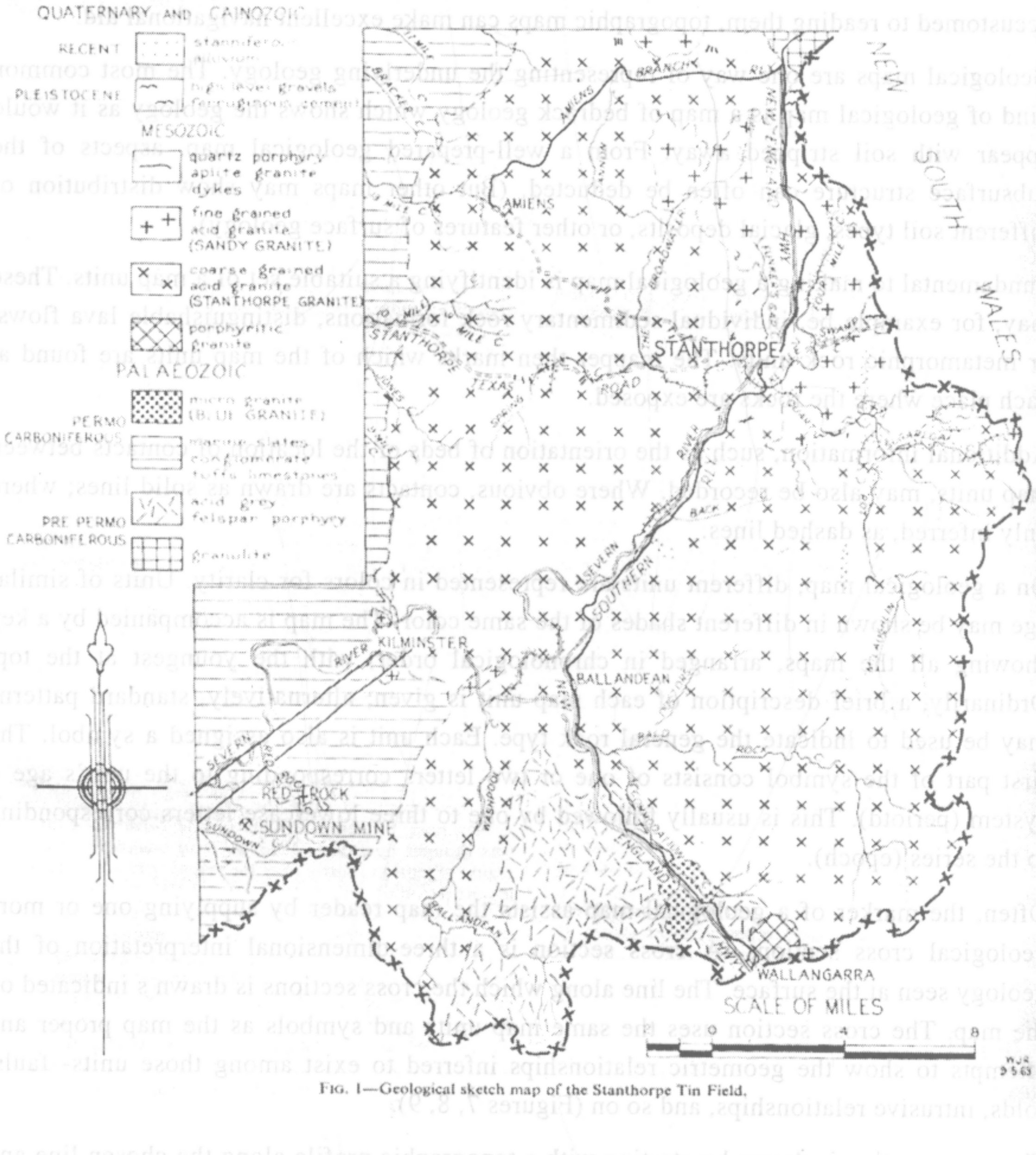


FIG. 1—Geological sketch map of the Stanthorpe Tin Field.

**Figure 7.** Geological map of the Stanthorpe Tinfield.

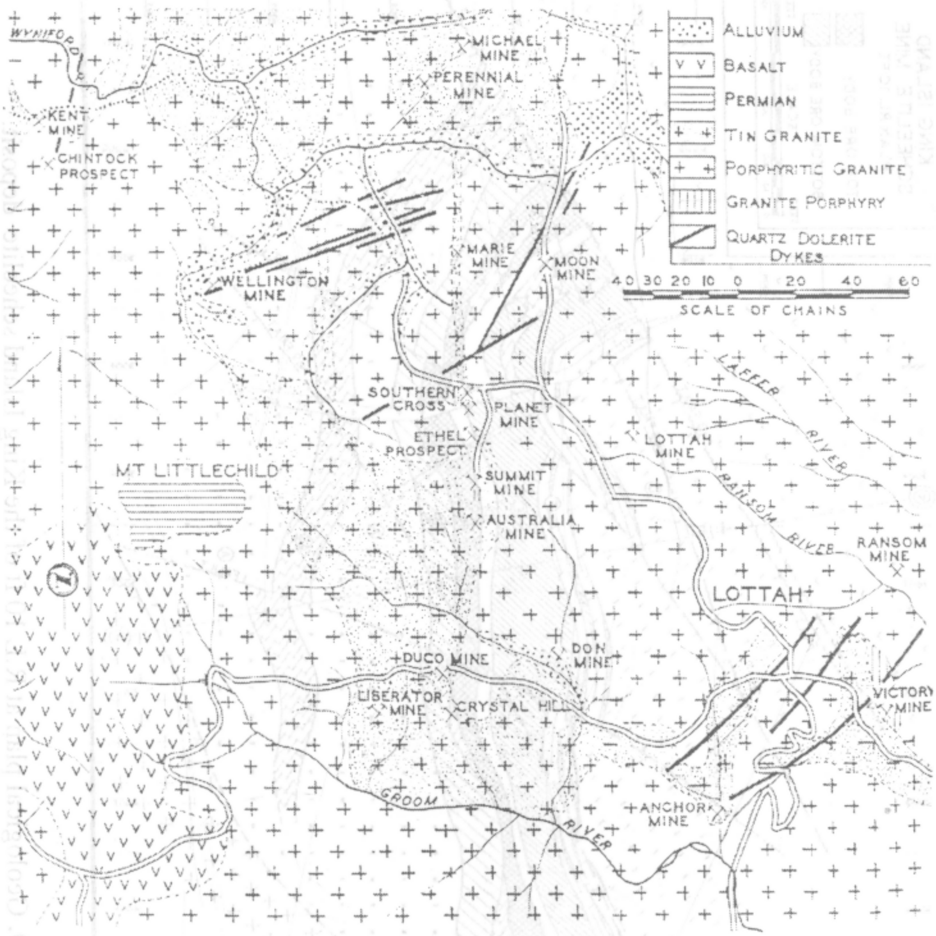



FIG. Geological map of Blue Tier Tinfield

**Figure 8.** Geological map of Blue Tiger Tinfield.

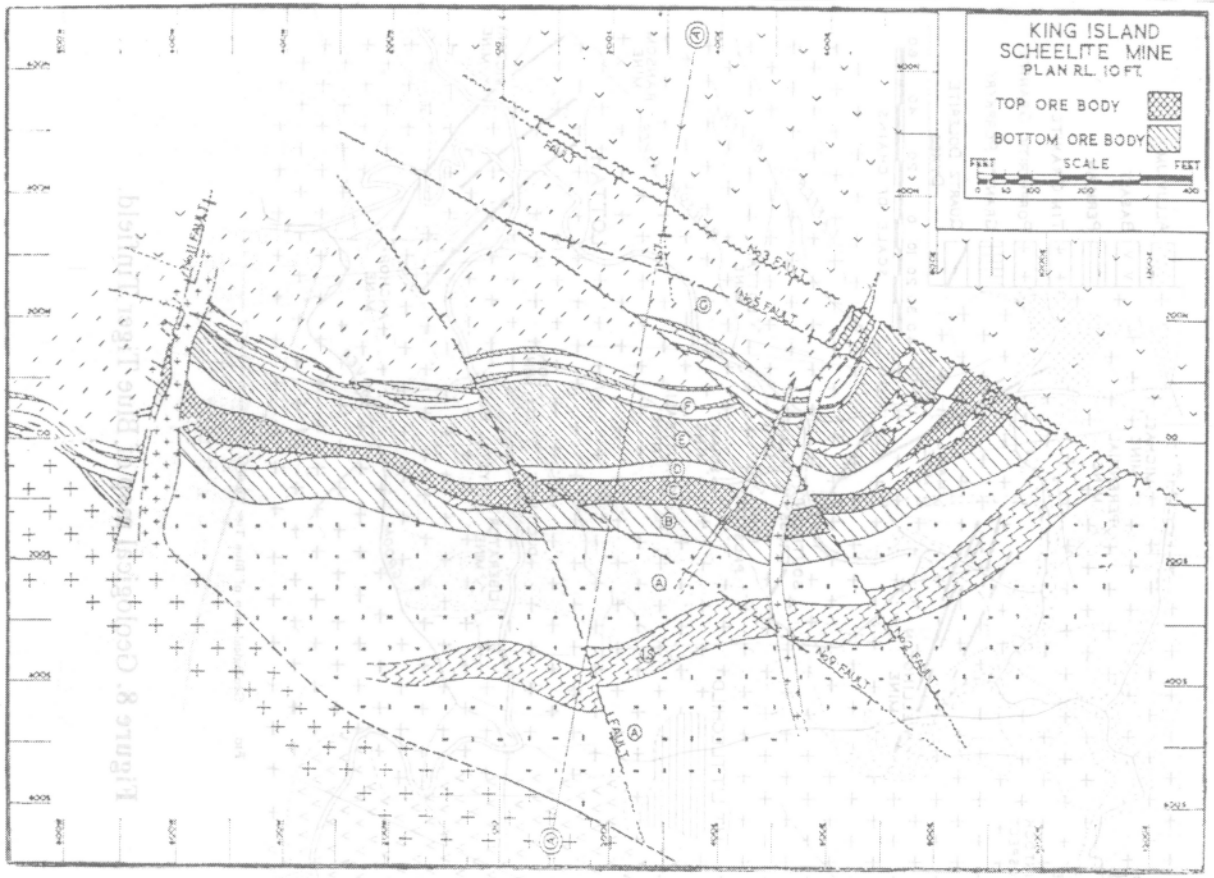



**Figure 9.** Geological plan at R.L 10 ft of the King Island scheelite deposit.

## VOCABULARY

| | |
|---|---|
| Topographic map | Bản đồ địa hình |
| Geological map | Bản đồ địa chất |
| Subsurface structure | Cấu trúc dưới mặt đất/ dưới sâu |
| Be deducted | Bị giảm đi |
| Rocks are exposed | Đá lộ ra |
| Inferred (adj) | Dự đoán |
| Chronological order | Theo thứ tự tuổi |
| Be assigned | Được gán cho |
| Geological cross sections | Mặt cắt địa chất |
| Thre-dimensional interpretation | Giải thích trong không gian ba chiều |
| Fauls; folds | Đứt gãy; nếp uốn |
| Intrusive | Xâm nhập |
| Unique (adj) | Duy nhất/dị thường |
| Plausible alternatives | Biến đổi hợp lý/logic |
| Mineral exploration | Thăm dò khoáng sản |

## II.2. LITHOSPHERE

The globe of the Earth is clad in a hard stony cover which is called lithosphere. The thickness of the lithosphere averages about 100 kms. Under the lithosphere there is a molten mass called magma. It is supposed that the thickness of the magma's layer is over 1000 kms. Under the magma there is earth kernel. Judging by the great weight of the kernel and by the magnetic nature of the Earth one can suppose that the Earth's nucleus consists of the kernel of iron, nickel and other metals. A part of its metals penetrate into the magma, and magma in its turn penetrates through fissures into the earth's crust. Here it is slow cooled down making "veins" and give origin to various ores and metals. The more magmatic veins, the greater the number of places where ore can be found. The richest deposits are in the lower strata of the lithosphere. The greater part of the earth's surface is covered with water. The dry land emerges from the sea only in portions of various size. The greater portions are called continents, or main-lands, and the small ones are called islands.

The rivers, the lakes, swamps, ground waters and glaciers make altogether a dense water net. Thus the lithosphere is almost entirely enveloped in the water cover or hydrosphere. The final covering of the earth is air cover, or atmosphere. The thickness of the atmosphere is about 500 kms.

## II.3. THE STRUCTURE OF THE EARTH'S CRUST

The crust of the Earth is very thin layer on the surface, like the sin of an orange. It is thickest under the mountains and thinnest under the ocean basins. It contains allthe materials used by man, e.g. oil, copper and gold. The liquid part of the crust is called the hydrosphere and this consists of all the water on the Earth. The solid part of the crust is call the lithosphere and iscomposed of rocks and minerals.

There are three types of rocks: metamorphic, sedimentary and igneous.

Metamorphic and sedimentary rocks are divided into strata. Usually the oldest rocks are at the bottom and the youngest are at the top. Igneous rocks usually intrude through the strata, as in the conduit in the diagram, and therefore younger than the rocks surrounding them.

The crust of the Earth as we know already has a thickness which averages about 100 kms. The deepest borings can reach only 2 - 2,5 kms. It would seem that we cannot explore the structure of the Earth's crust deeper than 2,5 kms. But it is not so. Some means have been found to study the lithosphere much deeper than that. Let us take an example. Before us we see broken up mountains. Looking at the drawing we notice that there are layers of limestone at a depth 4 - 5 kms. But the same layers on the summit can be seen on the surface.

The layers of dolomite situated at a depth of 6 - 7 kms come out also on the surface. The older the mountains, the more they have been subjected to the average of the elements, the more the deepest strata of lithosphere are seen on the surface not for one or two, but for scores of kilometers.

In search of minerals man has been studying mountains with a great attention. As a result, we have now a rather clear picture of the internal structure of the Earth's crust.

## II.4.1 SEDIMENTARY ROCKS

Clay, sand, gravel and other soft rocks are easily washed out and carried by water. Quick streams carry not only sands and gravels, but even stones. When the stream becomes slower the larger soft stones are precipitated on the bottom. When the stream reaches the plain or comes into the lake it stops altogether. Under such conditions the sediments begin to collect. Such materials as clay, sand and even the finest slime settle on the bottom. It takes place in even horizontal layers.

On plain the surface of the lithosphere consists usually of soft stones: clay, sand, etc... They are found mostly in strata. They were precipitated by water. In some cases soft stones can be precipitated also by the air. Thus, in deserts we observe precipitation of dust and fine sand. All stones which are precipitated by water or air are called sedimentary rocks.

The layers of sand, clay and other soft materials are covered with new strata of sedimentary rocks and so can be found in deep under the Earth. Upper strata press by their weight against the lower strata and compress them together. Filtrating waters from above bring solutions of some salts and consolidate or, as it is said, cement the soft rocks. As a result the soft rocks become hard stone rocks. Thus from clay we have loamy schists, from sand - sandstone, from gravel- conglomerate, from precipitated sea shells - limestone, from remnants of plants - coal, etc...

In the sandstone and especially in the loamy schists, one meets rather often traces and prints of leaves, shells, fishes and other water animals. This once more testifies that all strata of sandstones and loamy schists were long time ago precipitated by water.

## II.4.2 SEDIMENTARY ROCKS

The sedimentary rocks form an outer skin on the Earth's crust, covering three-quarters of the continental areas and most of the sea floor. They vary in thickness up to 10 km. Nevertheless they only comprise about 5% of the crust.

Most sedimentary rocks are formed from the breakdown products of pre-existing rocks. Accordingly, the rate of denudation takes place acts as a control on the rate of sediment, which in turn affects the character of sediment. Denudation may be regarded as a cyclic process. Each cycle of erosion is accompanied by a cycle of sedimentation. Geological structure also influences the rate of breakdown. Furthermore the amount of sedimentation is affected by the amount of subsidence which occurs in a basin of deposition.

The particle of which most sedimentary rocks are composed have undergone varying amount of transportation. In order to turn unconsolidated sediment into a solid rock it must be lithified. Lithification involves two processes, namely, consolidation and cementation and depends upon its composition and texture and the pressures acting on it (the weight of overburden).

The texture of a sedimentary rock refers to the size, shape and arrangement of its constituent particles. Because of their smallness, the size of grain of sands and silts has to be measured in directly by sieving and sedimentation techniques respectively. Individual particle of clay have to be measured with the aid of an electron microscope. The results of size analysis may be presented graphically by frequency or histogram. More frequently, however, they are used to draw cumulative curve.

Certain sedimentary rocks are the products of chemical or biochemical precipitation whilst others of organic origin. Thus, the sedimentary rocks can be divided into two principal groups:

1. Clastic or exogentic types; and

2. Non-clastic or endogenetic types

However, one factor which all sedimentary rocks have in common is that they are deposited and this gives rise to their most noteworthy characteristic, i.e. they are bedded or stratified.

A gravel is an unconsolidated accumulation of rounded fragments. When a gravel becomes indurated it forms a conglomerate. Sands consist of a loose mixture of mineral grains and rock fragments. The process by which an sand is turned into a sandstone is partly mechanical, involving grain fracturing, bending, and deformation. Silstones may be massive or laminated. Deposits of clay are principally composed of fine quartz and cly minerals. The term limestone is applied to those rocks in which the carbonate fraction exceeds 50%, over half of which is calcite or aragonite.

Shale is the commonest sedimentary rocks and is characterized by its lamination. Sedimentary rocks of similar size range and composition, but which is not laminated, is usually referred to as mudstone. Peat deposits accumulate in poorly drained environments where the formation of humic acid gives rise to deoxynated condition.

## II.5. TEMPERATURE OF THE EARTH

The terrestrial surface obtains its heat from the Sun. The Sun's heat does not penetrate deep into the Earth. Long observations have shown that at the depth of 20 - 30 m the temperature does not change at different seasons of the year. But if we dig deeper than 30 m we shall notice that the temperature of the Earth is gradually increasing all the time. Numerous observations made in digging of shafts, tunnels and borings have shown that in digging for every thirty three meters the temperature increases by $1^0$. On this basis we can make calculation for various depths of the Earth. Thus if at the depth of thirty meters the temperature is $5^0$, at the depth of 500 m it must be 19 - $20^0$, and at the depth of 1000 m – $40^0$, etc...

Actual observations confirm our calculations. One of the deepest borings of 2,440 m of the depth is in the Upper Silosia. It is known that the temperature at the depth of 2,220 m is $83^0$. All these observations refer only to the uppermost strata of the lithosphere. But have we any reason to believe that the temperature increases further? Yes, this is confirmed by the following facts: there are hot springs coming from the depth of the Earth, there are volcanoes, which throw up blazing ones and melted lava with a temperature of many degrees.

## II.6. FORMATION OF MOUNTAINS

In some places the Earth's crust undergoes large scale shifts. In such shifting the layers of the Earth's crust are bent, gathered in folds and marked by fissures and cracks. The result of that shifting is the formation of mountains. Anyone who has been in a mountainous region has noticed that the rock strata are different in contour from those found in a level region. Very often the mountain rock beds are gathered in folds of various sizes and shapes. Sometimes the layers are cut with deep transversal cracks and the position of the strata on either side has been shifted. Such shifting of the layers is called faults. If the mountains have many folds they are called *folded mountain*. As examples of folded mountains we can name the Caucasian Mountains, the Alps, the Himalayas, the Co-dillerats, etc.... The mountains where the above faults predominate are called *faulted mountains*. Such are the Transbaikal, Juguli Mountains and others. The faults and folds can be met often in mountainous localities.

Sometimes cracks and fissures in the Earth's crust are very deep, reaching the layer of magma. Through such fissures molten substances can rise and emerge at the surface. Volcanic processes are the result of such outlets of melted masses to the surface.

## II.7. VOLCANISM

The volcanoes are mountains which are erupting from the depths of the Earth gases, blazing stones and a molten liquid mass called lava. The hole of the channel through which volcanic matter is erupted is called a crater.

The thickness of the lava varies. If it is very thick it gets hardened while in the volcano's crater and clogs it. Then the accumulated gases burst up the hardened lava with enormous force and turn it into fine powder (volcanic ash).

At such explosions large pieces of lava are also thrown out from the crater (volcanic bombs). If the lava is in the liquid state it comes out without explosions and quickly flows down the slopes. Not only has the character of the eruption depended upon character of the lava, but also the external appearance of the volcano. If the latter erupts hardened lava in the form of the stones and ashes it looks like a pile of sand with a flattened top. But if the volcano erupts liquid lava, then its slopes get covered by lava. Such slopes are slant, the volcano appears flat from a distance.

During eruption, the volcano presents a terrifying aspect. From the crater a column of burning gases and steam as well as thick clouds of volcanic ash rise to an enormous height. Incandescent stones of different sizes fly out together with the ash. An awful rumble and din comes from under the Earth. Very often thick clouds gather over volcanoes and a storm begins. The rain mixed with ash descends on the Earth like so much hot dirt. It has happened that whole towns have been entirely covered, first with ash and then with a blanket of lava. This was the case with Herculaneum, Pompeii and Stabia which were covered with ash about 2,000 years ago. Now they are being dug out and their ruins can be seen near Naples in the Apennine Peninsula (Italy). In 1902 the American city of San-Sierre, which had over 4,000 inhabitants was destroyed by the eruption of a volcano.

Several volcanoes are in our own territory, for instance Kamchatka has over thirty. The loftiest among them is the Kluchevskaya volcano – 4816 m high. In fact this is one of the highest volcanoes in the world. Volcanic lava has been slowly cooling for many years. There are places where the eruptions occurred several thousands years ago, but through the crack of the cooled lava columns of hot steam and boiling water (geysers) are still coming out or in some cases hot springs; such hot springs are numerous in Kamchatka. Beside the acting volcanoes there are many extinct ones. They can be seen on the Caucasus and in Transbaikal.

The massive rocks come from cooling of melted liquid masses. If such cooling proceeds quickly (on the surface) then we have massive non-crystallic rocks (lava). If cooling happens deep in the lithosphere then we have massive crystallic rocks (granites). The crystals are formed by the very low cooling of a melted mess and under great pressure. The slower the cooling, the larger are the crystals (coarse – grain granite). When the cooling happens in the fissures of the Earth's crust, we have on top fine crystallic rocks and bellow – large crystallic rocks. Slow cooling is very good for making ores. When cooling happens quickly there cannot be any ore. This fact makes it clear to us, why the lower strata of lithosphere have more ore deposits than the upper ones.

## II.8. PERPETUAL ROCKING OF THE DRY LAND

When mountains are destroyed, the products of destruction - clay, sand, stones, etc... are moved down to the lower places. So destruction and demolition continue all the time. As a result, after several thousands of years the mountains will be lower and their weight will be reduced. The eroded mountainous place will slowly rise up. Quite the opposite process happens in the low places. There the sediments of clay, sand and stones will increase the weight of the place and it will slowly plunge into the magma. Both processes of rising and sinking are very much developed on the Earth's surface. It is impossible to notice them by the naked eye because they take place very slowly.

On the Apennine Peninsula near the city of Naples, there are some ruins of an old temple. The temple was built on the sea shore more than 2000 years ago. The shore on which the temple stood began slowly to sink. In 1200 years it sank twelve meters and the temple was submerged in water. Eventually the temple began to rise again and at present it has risen already six meters but its foundation is still in water.

How slowly such changes take place, is to be seen from the following example. On the shores of the Gulf of Finland about 200 years ago some marks were cut on the local granite rocks. At present these marks are two meters higher than before. This shows that the whole locality is rising by one meter in 100 years.

That formerly even greater rising and sinking of the Earth's crust had taken place is proved by the fact that on the dry land we find large thick layers of pelagic sediments, chalk, limestone and other rocks of pelagic origin. They cover over two-thirds of the dry land surface.

## II.9. VOLCANISM AND FISSURES IN THE EARTH'S CRUST

Explorations have shown that volcanoes are present only where there are deep cracks in the Earth's crust. The majority of cracks are situated on the shores of the Pacific - the Great Ocean making what is called the Pacific Volcanic Ring. Here we also find the majority of volcanoes. Altogether there are about 400 volcanoes in the world and 300 of them are near the Pacific. They stand in long rows on the shores of the Asiatic and American continents and islands (the Kamchatka, Philippines, Sunda and other volcanoes). Many of them rise directly from the bottom of the sea making chains of the Kurille islands, and the majority of other small islands of the Pacific. Many volcanoes are scattered also over the islands of the Mediterranean Sea, Caribbean Sea, ets.

Magma lyings under the Earth's crust can rise rather high in the fissures for the simple reason that the Earth's crust is heavily pressing on magma. It can be compared with water rising in the whole cut in winter because the ice is pressing on water. The magma while rising heats and melts the walls of the cracks and fissures. Then great quantities of gas and steam accumulate. The gases having no outlet are partly dissolved in magma and partly accumulated the top of the cracks.

## II.10. METAMORPHISM AND METAMORPHIC ROCKS

Metamorphic rocks are derived from pre-existing rock types and have undergone mineralogical, textural and structural changes. The latter have been brought about by changes which have taken in the physical and chemical environments in which the rocks existed. The processes responsible for change give rise to progressive transformations which take place in the solid state. The changing conditions of temperature and/or pressure are the primary agents causing metamorphic reaction on rocks. Individual minerals are stable over limited temperature-pressure conditions which mean that when these limits are exceeded mineralogical adjustment has to be made to establish equilibrium with the new environment. Grade refers to the range of temperature under which metamorphism occurred.

When metamorphism occurs there is usually little alteration in the bulk composition of the rocks involved with the exception of water and volatile constituents such as carbon dioxide. Little material is lost or gained and this type of alteration is described as an isochemical change. By contrast, allochemical changes are brought about by metasomatic processes which introduce or remove material from the rocks they affect. Metasomatic changes are brought about hot gases or solutions permeating through rocks.

Two major types of metamorphism may be distinguished on the basis of geological setting. They are thermal or contact metamorphism and regional metamorphism. For examples: quartzite, quartz schist, gneiss, marble, granulite, schist, amphibolite, green schist, slate, etc...are metamorphic rocks.

## VOCABULARY

| | |
|---|---|
| Lithosphere | Quyển đá, thạch quyển |
| Magma | Macma |
| Kernel | Nhân |
| Crust | Vỏ |
| Deposit | Mỏ khoáng |
| Hydrosphere | Quyển nước, thủy quyển |
| Iron | Sắt |
| Nickel | Niken |
| Explore (v) | Thăm dò, khảo sát |
| Metal | Kim loại |
| Boring | Khoan, sự khoan |
| Layer | Lớp |
| Internal structure | Cấu trúc bên trong |
| Dolomite | Đolomit |
| Clay | Sét |
| Sand | Cát |
| Gravel | Cuội |
| Sediments | Vật liệu trầm tích |
| Sedimentary rock | Đá trầm tích |
| Sedimentary stone | Đá trầm tích |
| Loamy schist | Đá phiến sét |
| Sandstone | Cát kết |

| | |
|---|---|
| Gravel | Cuội |
| Conglomerate | Cuội kết |
| Filtration water | Nước thấm lọc |
| Massive rocks | Đá kết tinh dạng khối |
| Melted liquid masses | Vật chất nóng chảy, dung thể macma |
| Crystalline rocks | Đá kết tinh |
| Ore | Quặng |
| Ore deposits | Các mỏ quặng |
| Terrestrial surface | Mặt đất |
| Penetrate | Xuyên |
| Melted liquid magma | Dung thể macma nóng chảy |
| Submerged | Bị chìm |
| Volcano | Núi lửa |
| To protrude | Xâm nhập |
| Destruction | Sự phá hủy |
| To destroy | Phá hủy |
| Demolition | Sự phá hủy |
| Eroded mountainous place | Vùng núi xâm thực |
| To plunge into magma | Chuyển thành macma, nhấn chìm vào macma |
| To begin to rise again | Bắt đầu tái nâng lên |
| Has risen already | Đã nâng lên |
| Granite rocks | Đá granit |
| Pelagic sediments | Trầm tích biển |
| Pelagic origin | Nguồn gốc biển |
| Volcanism | Hoạt động núi lửa |
| To erupt | Phun trào |
| To blaze | Sáng chói, mãnh liệt |
| Crater | Miệng núi lửa |
| External appearance of the volcano | Biểu hiện bên ngoài của núi lửa |
| To descend on | Rơi xuống |
| Enormous | To lớn, khổng lồ |
| Hot spring | Suối nước nóng |

| | |
|---|---|
| Extinct (adj) | Tắt |
| The acting volcanoes | Núi lửa đang hoạt động |
| Extinct volcanoes | Núi lửa đã tắt |
| To undergo | Trải qua, chịu, bị |
| To shift | Dịch chuyển, trượt |
| To be gathered into folds | Tạo thành nếp uốn |
| Faults | Đứt gãy |
| Folded mountains | Núi uốn nếp |
| To predominate | Trội hơn, chiếm ưu thế |
| Faulted mountains | Núi đoạn tầng |
| Cracks | Khe nứt |
| Fissures | Khe nứt, đứt gãy |
| Outlets | Sự trào, sự dâng lên |
| To emerge | Trào ra, dâng lên, phun lên |
| Exploration | Sự khảo sát, sự thăm dò |
| Volcanic ring | Cung núi lửa |
| To make chains | Tạo nên các chuỗi, dãy mắt xích |
| To be scattered | Rải rác |
| Mediterranean Sea | Địa Trung Hải |
| Great quantities | Một số lượng rất lớn |
| Perpetual rocking | Sự tạo đá liên tục |
| Pelagiorigin | Nguồn gốc biển |
| Emerge at the surface | Trào lên mặt đất/ phun trào |
| Sedimentary rock | Đá trầm tích |
| An outer skin | Một lớp mỏng |
| Covering three-quarters | Phủ ba phần tư |
| Sea floor | Đáy biển |
| Denudation | Bóc mòn, mài mòn |
| Cyclic process | Quá trình có tính chu kỳ |
| Cycle of erosion | Chu kỳ xâm thực, bóc mòn |
| Basin of deposition | Bể/ bồn trầm tích |
| Must be lithified | Trở thành đá |

| | |
|---|---|
| Size, shape and arrangement of | Hình dạng, kích thước và sự sắp xếp của... |
| To be measured in directly by sieving | Có thể đo trực tiếp bằng rây, sàng |
| An electron microscope | Kính hiển vi điện tử |
| To draw cumulative curve | Vẽ đường cong luỹ tích |
| Exogentic (adj) | Ngoại sinh |
| Endogenetic (adj) | Nội sinh |
| Noteworthy (adj) | Đáng chú ý/ đáng ghi nhớ |
| Bedded or stratified | Phân lớp/ phân tầng |
| Metamorphism | Biến chất |
| Metamorphic rocks | Đá biến chất |
| Environment | Môi trường |
| Progressive transformations | Biến chất tiến triển |
| Establish equilibrium | Thiết lập sự cân bằng |
| Volatile constituents | Thành phần khí |
| Isochemical changes | Biến đổi đẳng hoá |
| Allochemical changes | Biến đổi phi đẳng hoá |
| Permeating through | Thấm qua |
| Geological setting | Bối cảnh địa chất |
| Contact | Tiếp xúc |
| Regional | Thuộc khu vực |
| Amphibolite | Amphibolit |
| Slate | Đá phiến sét |
| Green schist | Đá phiến màu lục |
| Schistosity | Tính phân phiến |
| Quartzite | Quaczit |
| Quartz schist | Đá phiến thạch anh |
| Gneiss | Gơnai |
| Marble | Đá hoa/đá cẩm thạch |
| Granulite | Granulit |

## II.11. THE NATURE OF THE EARTH'S CRUST

The crust forms the rigid generally britle outer layer of the earth lying above the Moho.

Apart from observations made and material collected at the surface; carried to the surface through geological processes such as volcanic activity or deep faulting; or brought to the surface through deep drillng programmes; our knowledge of earth's crustal character has been determined largely through interpreting geophysical measuments, in particular seismic and gravity data in the ligt of knowledge gained through high presure and temperature labaratories.

The Earth's crust can be divided conveniently in two readily distinguished crustal types-continental crust and ocenic crust , and both types will be examined seraparately.

### I. Continental crust

Variation in seismic velocities with depth reflect sympathetic variation in either crustal chemical or mineralogical phase changes. Presure generally increases with depth principially due to lithostatic forces. Temperatures increase with depth at an average rate of $25^0$C/km above the Moho but decrease to about haft this value below the Moho due to the absence of radioactivive heat sources. The highest crustal levels are represented by surface and near surface activity including areas of erosion, sedimenation and vocalnism (Figures 10).

The average crustal density of around 2.77 - 2.82 is significant higher than that of granite (2.67). The actual average crustal density corresponds to a rock type somewhere between grnodirite and diorite in composion.

Crustal thickening through fold and faul induced lateralcrustal shortening and vertical thrust stacking are resonable and demonstrable mechanism.

Some 12 divisions are recognised on the basis continental of ocenic affinity, relative stability, morphology and structure. They are the following: shiels, platforms, Paleozoic orogenic belt, Mesozoic-Cenozoic orogenic belt, continental rift system, volcanic island, island-arc, trench, ocean basin, oceanic ridge, marginal-sea basin, inland-sea basin.

### II. Ocenic crust

Seismic studies cofirm that the oceanic crust is very thincomperad to continental crust (6 - 7 km beneath an avegage water depth of 4.5 km). It may be divided into three discernible layers (Figures 11, 12):

- Oceanic Layer 1: These deep sea sediments, average thicness is 0.4 km.
- Oceanic Layer 2: These layer is igneous in origin and is dominated by tholietic olivine

basalts with pillow lavas a dominant feature. Layer 2 is variable in thickness, ranging from 1,0 to 2.5 km.

- Oceanic Layer 3: Layer 3 is the main component of the oceanic crust and represents its plutonic foundation. The Layer 3 can be divided into two sub-layer: upper layer of gabbroic composion with some pockets of plagiogranite.

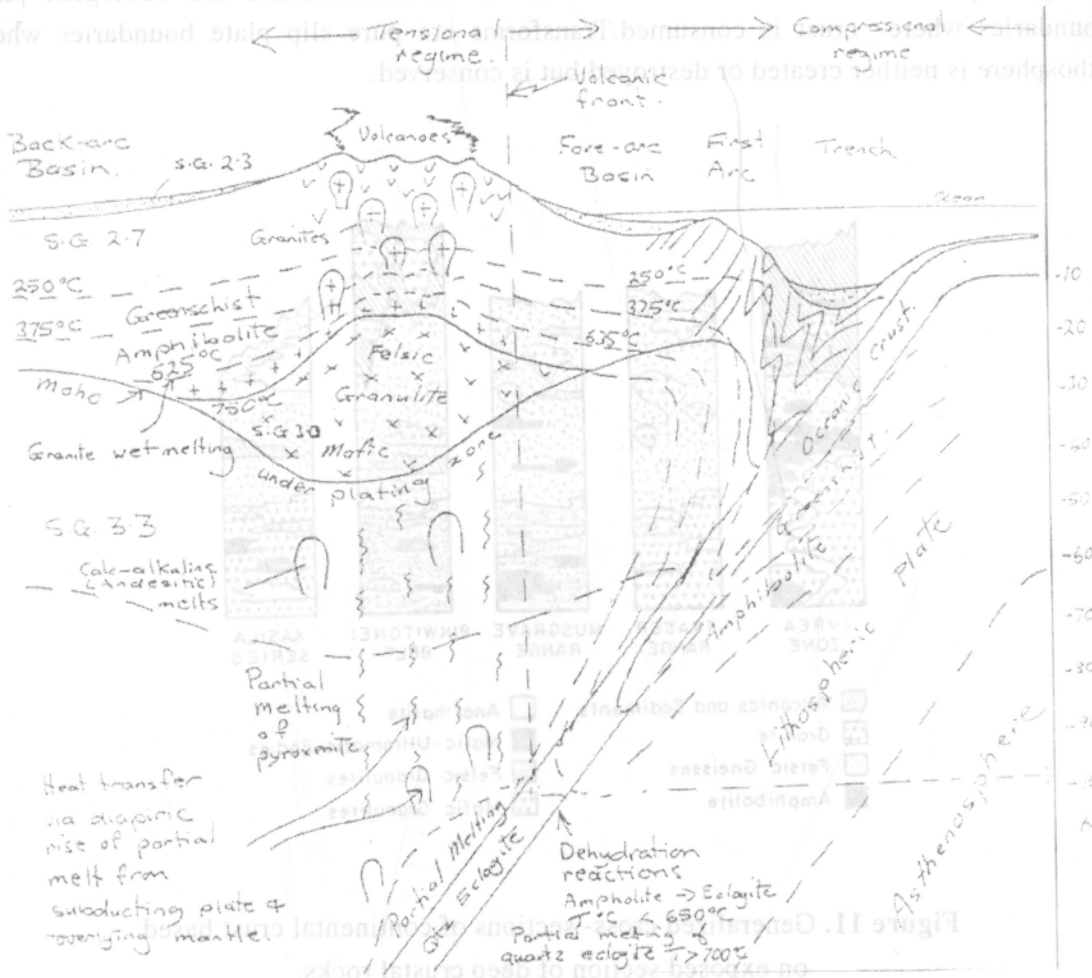



**Figure 10.** Schematic cross section through continental crust.

The lower sub-layer consists of cumulate gabbro and ultrabasic rocks formed by crystal settling wich may be serpentinized at depth. The Earth's crust consists of plates. The pricipal tenant of plate tectonic theory is the existance of a rigid system of crustal plates whose relative movements driven by the deep heat engine of the Earth's interior is manifest at the boundaries between adjacent plates. Here major tectonic processes and events are located and depending on the nature of relative movements consuming, translational or extensional plate boundaries of distinctive geological chracter can be recognised. Boundaries exist between two or more plates and stable configurations of three plates are not uncommon over log periods of time.

There are three types of plate boundary: ridges, trenches and transforms. Ridges are divergent plate boundaries where new crust is created.Trenches are covergent plate boundaries where crust is consumed.Transforms are pure slip plate boundaries where lithosphere is neither created or destroyed but is conserved.

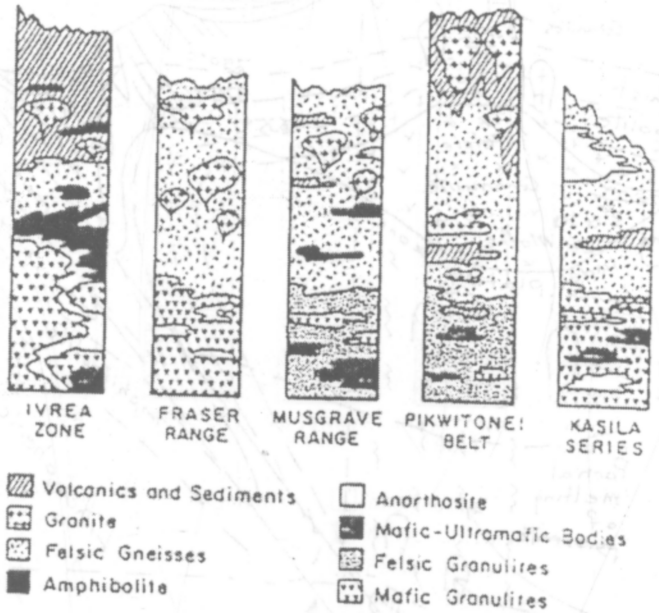



**Figure 11.** Generalized cross- sections of continental crust based on exposed section of deep crustal rocks.

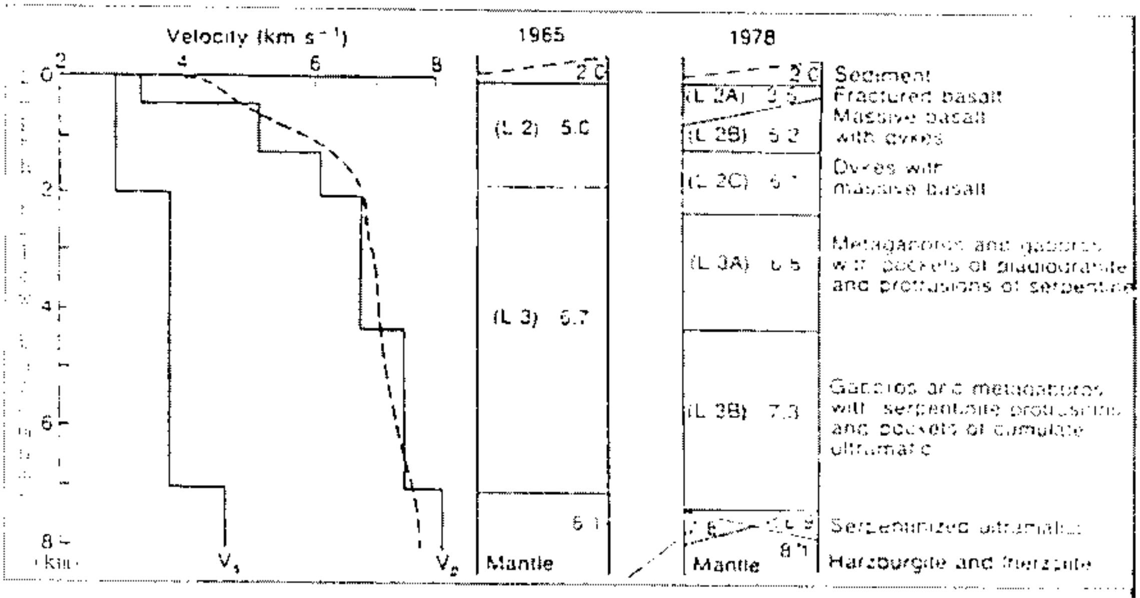



**Figure 12.** P and S wave velocity structure of the oceanic crust and its interpretation in terms of layered models proposed in 1965 and 1978. Numbers refer to velocities in km/s. Dashes curve refers to graditional increase in velocity with depth (after Spudith and Orcultt, 1980 and Harison & Bonati, 1989).

## VOCABULARY

| | |
|---|---|
| Britle outer layer | Lớp vỏ cứng ngoài cùng |
| Earth's crustal character | Đặc tính của vỏ trái đất |
| Interpreting geophysical measuments | Giải thích tài liệu địa vật lý |
| Continental crust and ocenic crust | Vỏ lục địa và vỏ đại dương |
| Seismic velocities | Tốc độ địa chấn |
| Lithostatic forces | Áp lực thuỷ tĩnh |
| Radioactivive heat sources | Nguồn năng lượng phóng xạ |
| Stacking adj | Chất đông, chồng chất |
| Shiels, platforms | Khiên, nền |
| Orogenic belt | Đai tạo núi |
| Volcanic island | Đảo núi lửa |
| Island-arc, trench | Cung đảo, vực biển |
| Oceanic ridge | Sống núi đại dương |
| Marginal-sea basin | Trũng biển rìa |
| Inland-sea basin | Trũng biển nội lục |

| | |
|---|---|
| Discernible | Có thể nhận thức rõ, thấy rõ |
| Pillow lavas | Dung nham dạng gối |
| Cumulate gabbro | Gabro dồn tích |
| Ultrabasic rock | Đá siêu mafic |
| Rigid system | Hệ thống cứng |
| Crustal plates | Mảng vỏ trái đất |
| Manifest | Hiển nhiên, rõ ràng |
| Consuming plate | Mảng hút chìm/ mảng chúc xuống |
| Translational | Mảng dịch chuyển |
| Extensional plate | Mảng tách giản/ căng giãn |
| Stable configurations | Cấu hình bình ổn |
| Pricipal tenant | Vùng đất chính |
| Transforms | Dịch chuyển/ Dịch trượt |
| Ridges | Dãy núi/ Sống núi đại dương |
| Trenches | Vực biển, hẻm vực |
| Divergent plate boundaries | Ranh giới mảng tách giãn |
| Covergent plate boundaries | Ranh giới mảng hội tụ |
| Slip plate boundaries | Ranh giới mảng dịch trượt |
| Is consumed | Bị hút chìm/ Bị chúc xuống |

# PART TWO: MINERAL DEPOSITS

## CHAPTER THREE: ENDOGENETIC MINERAL DEPOSITS

### III.1. DEPOSITS RELATED TO MAFIC IGNEOUS ROCKS

The deposits to be treated in this chapter are spesifically related to mafic rocks. Those igneous rocks range from among the largest, most extensive igneous petrologic systems in the wordl such as the Bushveld complex down to moderate-sized bodies like carbonatites. In each of them, the ore minerals are hosted by, and are therefore part of, the igneous rocks them-selves. With this in mind, the need to understand ream of economic geology legitimizes a subdiscpline known as economic geology, the bringing to bear of the tools and approaches of the petrologist to problems until recently explained by more generaleconomic geologists. The folowing descriptions bear heavily on thin-section petrology, polished-surface mineragraphy, and geochemistry, with the ppremise that we can not hope to understand the genesis and occurrence characteristics of spesific minerals like chromite unless we also consider the genesis of the kindred rocks formed with them. the scale of considerration is thus enlarged to include entire ore-forming petrologic systems (Figures 13, 14).

Ore deposits formed during fractional crystallization of magmas were recognised and named before Lindgren developed his classification system (Vogt. 1984). The term magmatic segregation deposit is now applied to all deposits that are direct crystallization product of a magma except for pegmatites, porphyry base-metal deposit, and others that involve hydro-thermal transport. They ussually form in the magma chamber, and thus are deep-seated intrusive bodies, but differentiatted or immiscible melt and crystal mushes can be drive in to magma chamber walls or roofs to form orebodies that are dikes, sills, and even extrsive flows.

Magmatic segration deposit may constitute an entire intrusive rock mass or a sing compositional layer within such a body, or it may be defined by the presence of valable accessory minerals in an otherwise normal igneous rock. The ore minerals may be early or late fractination products concentrated by gravitative settling of crystals or liquids, liquids immiscibility, or filter pressing, and may remain in place or be injected as an ore magma in to a previously solidified pluton or the surrouding country rock. The posibility that separation of immiscible magmatic liquids, such as sulphide or oxide liquid from a silicat melt, has been important in magmatic segregation ore formation was reemphasized by Fischer (1950), Hawley (1962), McDonald (1967), Philpotts (1967), MacLean (1969), and MacLean and Schimazaki (1976). Fischer and Philpotts dealt with magnetite-apatite fluids as immiscible fractions of a silicat melt and MacLean considered silicate-sulfied liquid immiscibility.

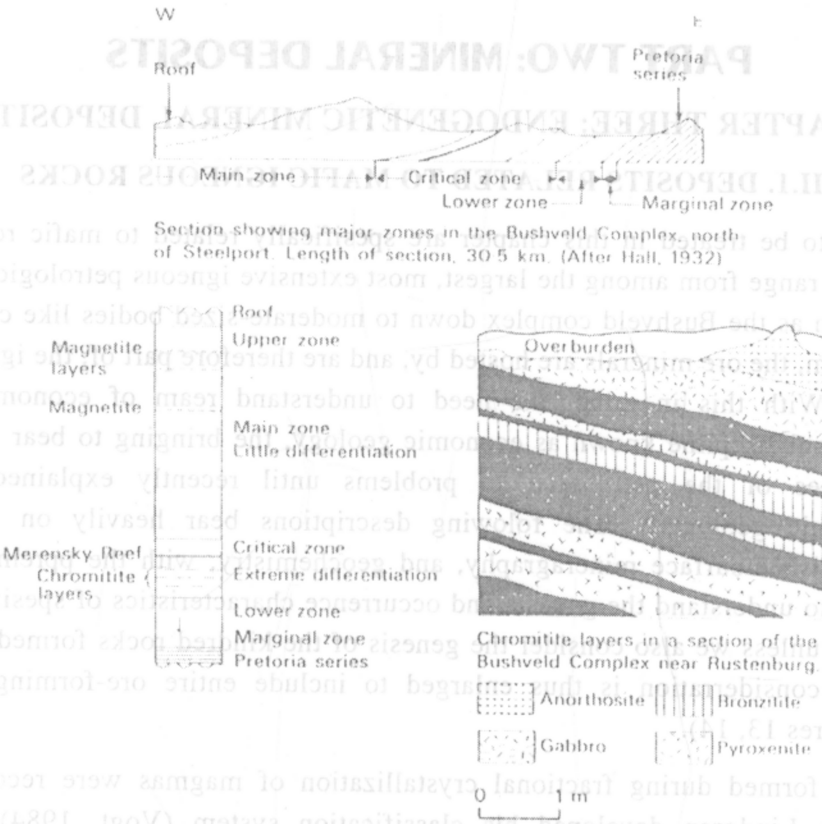



**Figure 13.** Deposit related to ultramafic/ mafic intrusive.

Certain ore minerals are characteristic of specific igneous rock, although others show no consistent affiliations. Ore commonly found with mafic rock include chromite, ilmenite, apatite, diamond, nickel, copper, and platinum group elements; those with igneous rock of intermidiate composition are magnetite, hematite, and such accessories as zircon, monazite, uraninite, and cassiterite. Many asssociations are even more restrictive, for axample chromite is closely associated with peridotite and dunite, or with serpentine derived from thes ultramafic rocks, in Alpine peridotie deposits (Thayer, 1946, 1969). The tendency toward a specific ore-host-rock association (Buddington, 1933) is one of the strongest line of evidence advanced by proponents of agmatic segregation as an ore-forming process. Deposits to be considered in this chapter are those that form as part of the mafic/ultramafic portion of igneous rock systems and intrusive setting. They are in general lodged in cratonic masses or at least in continental crust and include the largest ore-forming magnetic systems known, the layered mafic intrusions (LMI), of which the Bushveld igneous complex (South Africa), the Great Dyke (Zimbabwe), the Sudbury complex Canada), the Dtillwater complex and the Duluth complex (USA) are the best known examples.

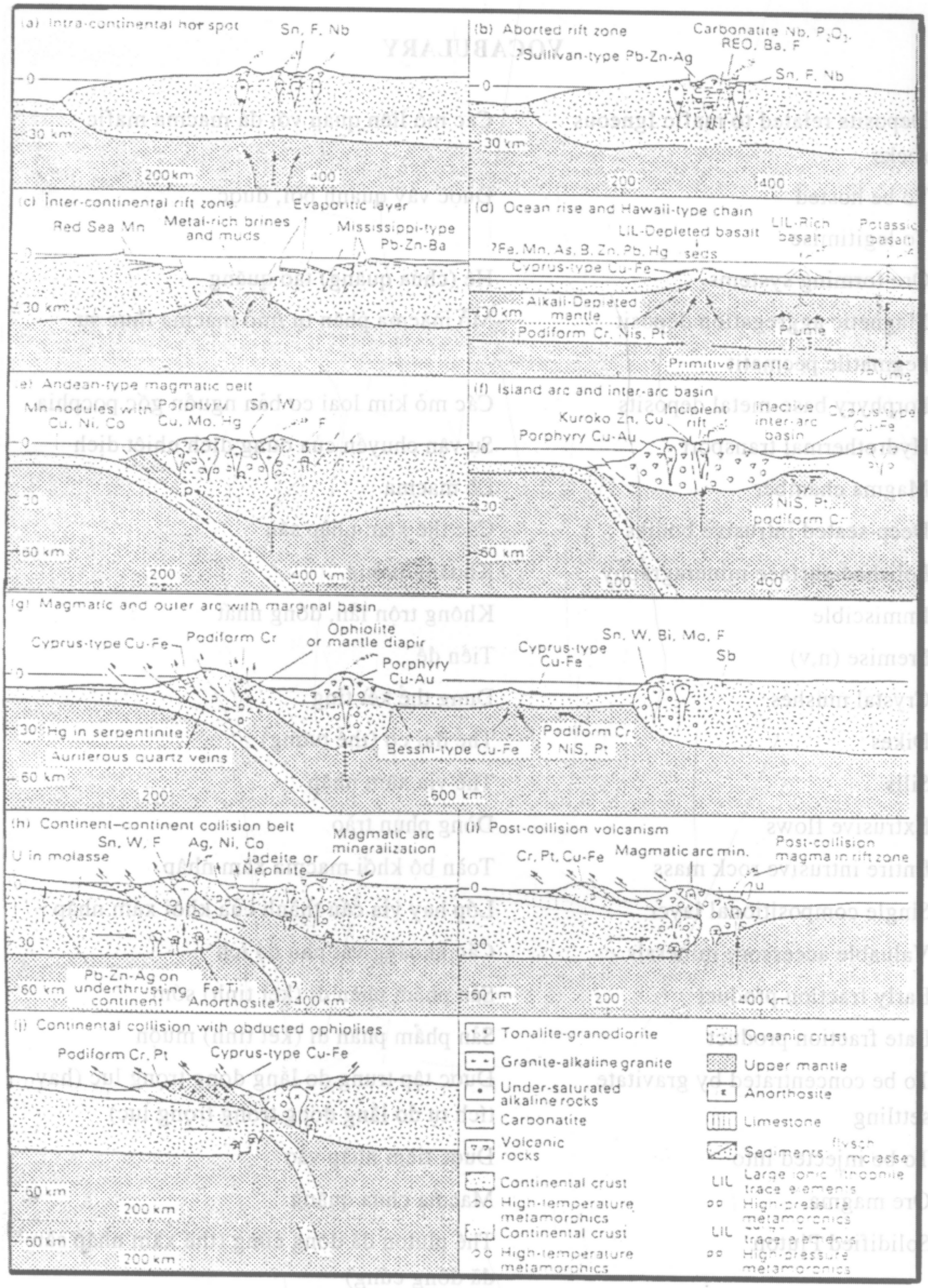



**Figure 14.** Schematic cross- sections through plate boundary - relates tectonic settings of mineralizion (from Michell & Garson, 1976).

## VOCABULARY

| | |
|---|---|
| Deposits related to mafic Igneous rocks | Các mỏ liên quan với đá macma mafic |
| To be hosted | Được vây quanh bởi, được |
| To legitimise | |
| Ore forming systems | Hệ (chứa quặng) tạo quặng |
| Magnetic aggregation deposit | Mỏ macma phân tụ /mỏ macma thực sự |
| Pegmatile pecmatit | |
| Porphyry base-metal deposits | Các mỏ kim loại cơ bản nguồn gốc pocphia |
| Hydrothermal transport | Sự vận chuyển của dung dịch nhiệt dịch |
| Magma chamber | Lò macma |
| Deep-seated intrusive bodies | Các thể xâm nhập sâu |
| Polished-surface mineragraphy | Khoáng tướng |
| Immiscible | Không trộn lẫn, đồng nhất |
| Premise (n,v) | Tiền đề |
| Crystal mushes | Dung thể kết ting |
| Dikes | Thể đai cơ (thể tường) |
| Sills | Thể vỉa xâm nhập |
| Extrusive flows | Dòng phun trào |
| Entire intrusive rock mass | Toàn bộ khối macma xâm nhập |
| Single compositional layer | Lớp hay vỉa cấu thành của khối xâm nhập |
| Valuable accessory minerals | Các khoáng vật phụ có ích |
| Early fraction product | Sản phẩm phân dị (kết tinh) sớm |
| Late fraction product | Sản phẩm phân dị (kết tinh) muộn |
| To be concentrated by gravitate settling | Được tập trung do lắng đọng trọng lực (hay tích tụ do lắng đọng trọng trọng lực) |
| To be injected into | Được tiêm nhập vào |
| Ore magma | Macma chứa quặng |
| Solidified Pluton | Thể pluton đã đông cứng (thể xâm nhập sâu đã đông cứng) |
| Silicate melt | Dung thể silicat nóng chảy |

| | |
|---|---|
| Silicate-sulfide liquid invisibility | Tính chất không trộn lẫn của dung dung thể silicat và dung thể sunfua |
| Consistent affiliations | Các mối liên kết vững chắc |
| Chromite | Cromit |
| Ilmenit | Inmenit |
| Apatite | Apatit |
| Diamonds | Kim cương |
| Copper | Đồng |
| Platinum group elements | Các nguyên tố nhóm bạch kim |
| Magnetite | Manhetit |
| Hematite | Hêmatit |
| Zircon | Ziacon |
| Monazite | Monazit |
| Uraninite | Uraninit |
| Cassiterite | Caxiterit |
| Peridotite | Peridotit |
| Dunite | Đunit |
| Ultramafic rocks | Các đá siêu mafic |
| Ore- host- rock association | Tổ hợp khoáng vật quặng và đá sinh cùng; tổ hợp khoáng vật chủ đá-quặng |
| Magmatic aggregation as an ore-forming process | Phân dị macma là một quá trình tạo quặng |
| Mafic portion | Phần mafic, hợp phần mafic |
| Igneous rock systems | Các hệ thống (các lớp) đá macma xâm nhập |
| To be logded in | Được lắng đọng ở; được định vị ở |
| Carbonic masses | Các khối địa khiên |
| Continental crust | Vỏ lục địa |
| Oceanic crust | Vỏ đại dương |
| Layered mafic intrusions | Các thể xâm nhập mafic dạng vỉa, sự xâm nhập mafic dạng lớp |
| Igneous complex | Phức hệ đá xâm nhập |
| To be bring found and explored | Đang được tìm kiếm và thăm dò |

## III.2. SKARN DEPOSITS

Rocks intruded by igneous masses are commontly recrystaled, altered, mineralized, and replaced, especially near the intrusive contact. These changes, caused by heat and by fluids emanating from or activatedby intrusives, have been collectively labelled igneous metamorphism, pyrometamorphism, pyrometasomatism and contactmetamorphism. Although each of these terms means roughly the same thing, igneous metamorphism is less restricve than the others, and many geologists prefer it.

Pyrometamorphism refer only to thermal effect and pyrometamorphism focuses upon replacement activity close to an igneous contact, Although many deposits in metamorphic rocks are found at considerable distance from any known intrusive massif. Pyrometamorphism may also refer to an alteration assemblage including skarn minerals that may be found at a contact, but the same minerals may also be found along veins or at considerable distance from a contact, not automatically implying high-temperature, high-pressure conditions (Titley, 1973). Igneous metamorphism can refer to all forms of alteration associated with the intrusion of igneous rocks. And thus is preferred general term. Howervcr, because the deposits to be described involve dominant metasomatic effect in the presence of metamorphic ones, non of these terms is really apt. So, Einaudi (1982) has recommended that the nongenetic term skarn be adopted.

Skarn- an old Swedish mining term for silicate gangue (amphibole, pyroxene, garnate, ect.) of certain iron and sulphide deposits of Archaen age, particurly those that have replaced limestone and dolomite.Its meaning has been generally expanded to include lime-bearing silicates, of any geological age, derived from nearly pure limestone and dolomite with the introduction of large amount of Si, Al, Fe and Mg.

Contact metamorphic aureoles around igneous bodies are known from metamorphic petrology. The newly formed rocks are generally very fine-grained, the so-called hornfelses. The process is essentially isochemical: the system is closed and no significant transport of matter takes place. When the counry rock is composed of readily reacting minerals, e.g. calcite, dolomite and argillaceous minerals, corse-grained skarn may be formed. Important metasomatic changes may occur where the emanations from the causative igneous body include aggressive volatile compounds (Fe, Cl, OH) and metal ions accumulated in the involuting melt of the igneous body (Mo, Sn, W,Fe, Cu, Pb,Se,Au and Ag). But also in this case large-scale transport of matter is only possible when the system is open due to primary or secondary rock porosity/permeability, e.g. karst formation or tectonic fracturing.

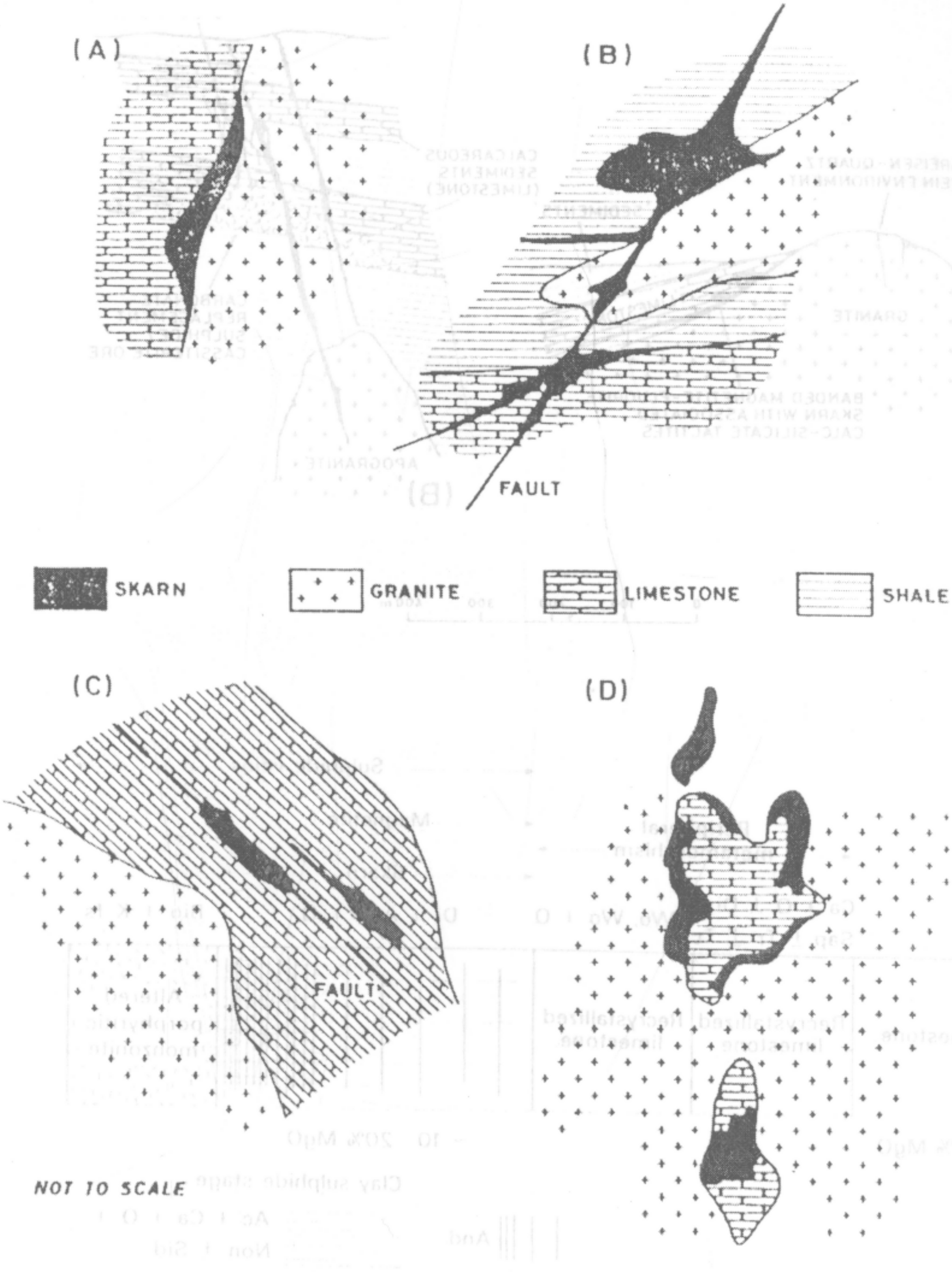
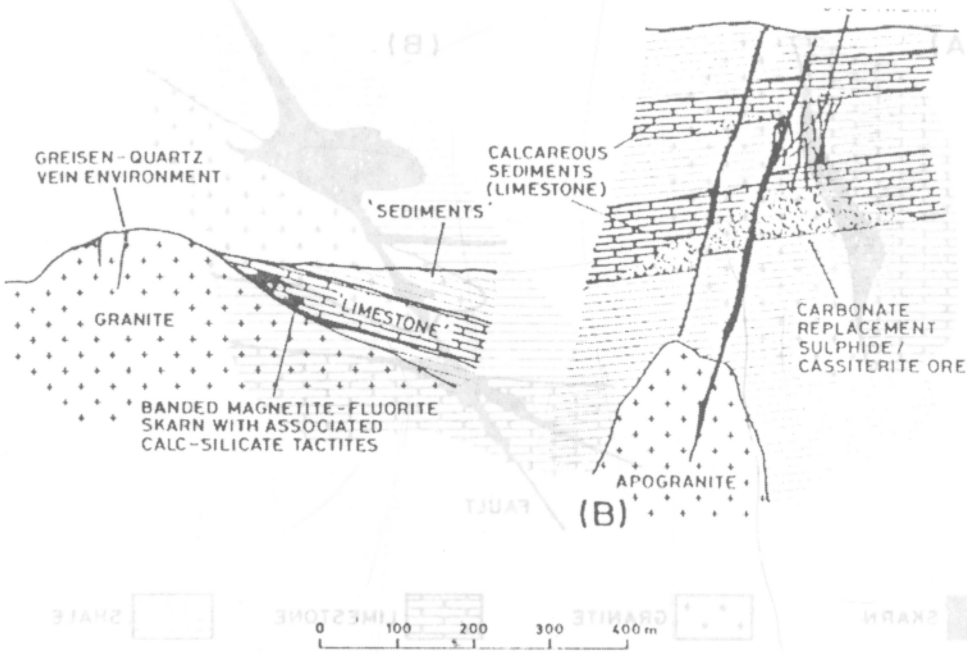



**Figure 15.** Different skarn deposits.



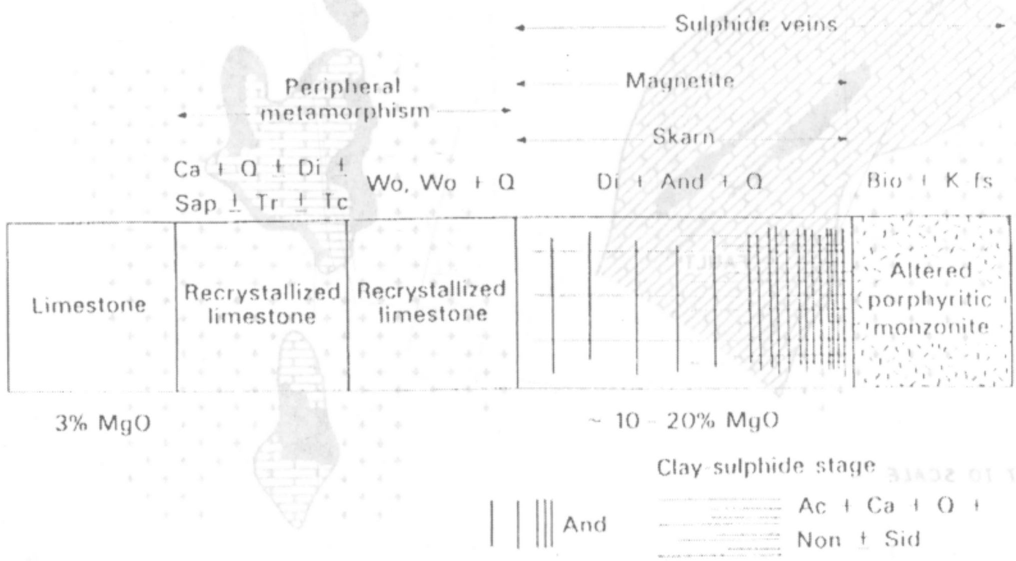




**Figure 16.** Zonation of mineral deposits at the Ely, Nevada (from Theodore, 1977).

Skarn ore bodies are in general irregular in shape and relatively small. In places they have a stratabound appearance due to the original stratification of Ca-rich and Ca-poor host rocks. A number of different metals are mined from skarn deposits:

1. Magnetite and hematite, some pyrite and chalcopyrite, and the usual Fe-rich contact mineral such as olivine, hedenbergite, andradite and ilvaite. Deposits occur in the Ural mountain (Russia), the island of Elba (Italy)
2. Cassiterite with wolfromite, scheelite, Bi, Zn and Fe minerals. Deposits are known from Czecoslovakia, Namibia, Australia.
3. Scheelite with sulphides of Bi, Zn,Fe,Mo,Cu,Pb well known from Canada, Nevada and USA, NE Brazil, Australia.
4. Molybdenite with other sulphides of Fe, Cu, Zn and some oxides.
5. Chalcopyrite with other sulphides of Fe, Zn, Mo. Mines are found in the western part of the USA, in Mexico, Roumania and New Guinea.
6. Sphalerite, galena with other sulphides of Fe, Cu, Zn.
7. Arsenopyrite-gold and gold deposits, a rather rare type has been mined in British Columbia, Canada.
8. Graphite with several small deposits and mines in the USA, Mexico, Srilanka and Grenvlle strict of Canada.

There are a number of skarn deposits that are most likely not related to igneous rocks. There include the classic magnetite-manganese deposits in Midle Sweden from where the name skarn derives, and the famous deposits of Franclin Furnace, New Jersy, USA. Here the main minerals are franklinite $(Fe,Zn,Mn)O.(Fe,Mn)_2O_3$ and willemite $Zn_2SiO_4$ (name for king Willem I of the Netherlands). In these deposits the skarn minerals and textures are not the results of contact metamorphism.There are no igneos rocks in the neigboorhood, but of high grade regional metamorphism of susceptible rocks adequate composition of possibly vocanogenic derivation.

## VOCABULARY

| | |
|---|---|
| Skarn deposit | Mỏ scacnơ |
| Recrystalize | Tái kết tinh |
| Alter (v); alteration | Biến đổi |
| Igneous metamorphism | Biến chất xâm nhập |
| Pyrometamorphism | Biến chất nhiệt |
| Pyrometasomatism | Biến chất trao đổi thay thế nhiệt |

| | |
|---|---|
| Contact metamorphism | Biến chất tiếp xúc |
| Nongenetic term | Thuật ngữ phi nguồn góc |
| Archaen (adj) | Thuộc Ackei |
| Lime-bearing silicate | Silicat chứa vôi |
| Aureole | Vành phân tán |
| Horfelse | Đá sừng |
| Isochemical (adj) | Đẳng hoá |
| Country rocks | Đá vây quanh |
| Argillaceous (adj) | Chứa sét |
| Volatite compounds | Các thành phần chất bốc |
| Porosity | Độ hổng |
| Permeability | Độ thấm |
| Exoskarn endoskarn | Scacnơ ngoài |
| Skarn-like deposit | Mỏ giống scacnơ |
| Susceptible | Dễ bị |

## III.3. HYDROTHERMAL PROCESSES

Thus far, ore-forming processes within the magmatic chamber have been considered first, then those operating just outside of the magma chamber during magma consolidation. This chapter pertains to a further step in magma consolidation that gives one variety of hydrothermal solutions, namely, hydrothermal mineralizing solutions, some of which are associated which magmas and others are not. These may be the direct source of epigenetic mineral deposits or they may be derived from meteoric or connate waters or metamorphic origin and still be hydrothermal solutions.

The term hydrothermal means hot water, and hot waters may originate by other than magmatic processes. They may be a mingling of waters as already mentioned or they may be meteoric, or connate, or the water content of minerals released during metamorphism that have become head within the earth and thus become hydrothermal solutions. Recent isotopic studies of hydrothermal solutions indicate that connate and meteoric waters play a more prominent role than hitherto recognized (Fid. 8-1). Also, Roedder, who has made extensive studies of the character and temperature of formation of fluid inclusions in ore deposit minerals, suggests that the Mississippi Valley type of deposits have been formed from modified, deep circulating, heated connate brine solutions carrying trace amounts of lead and zinc.

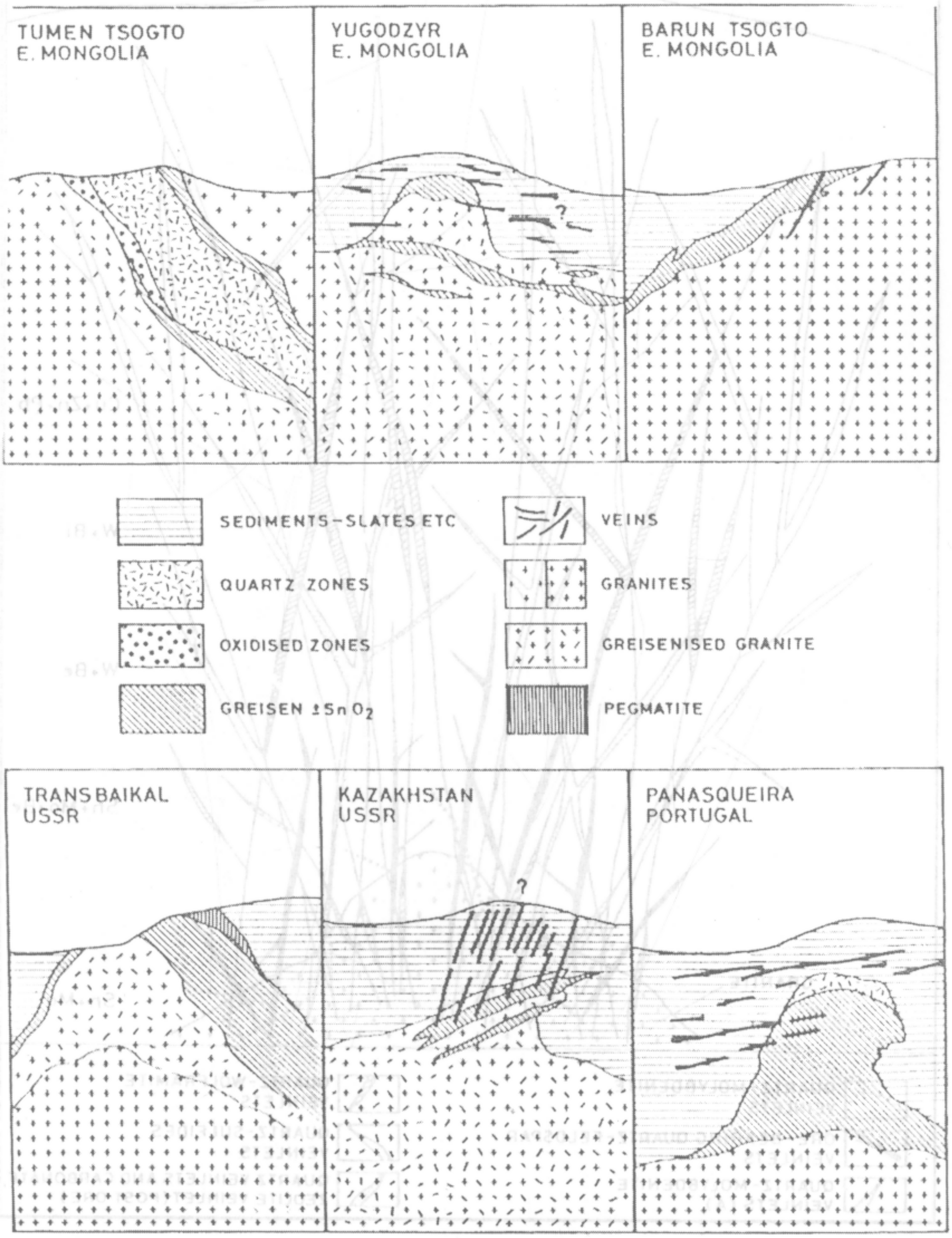



**Figure 17.** Examples of "the greisent-quartz cassiterite association" (after Rundqvusr et al, 1971), from R. G. Taylor (1979): Geology of Tin Deposits, Elsevier, Amstecdam.

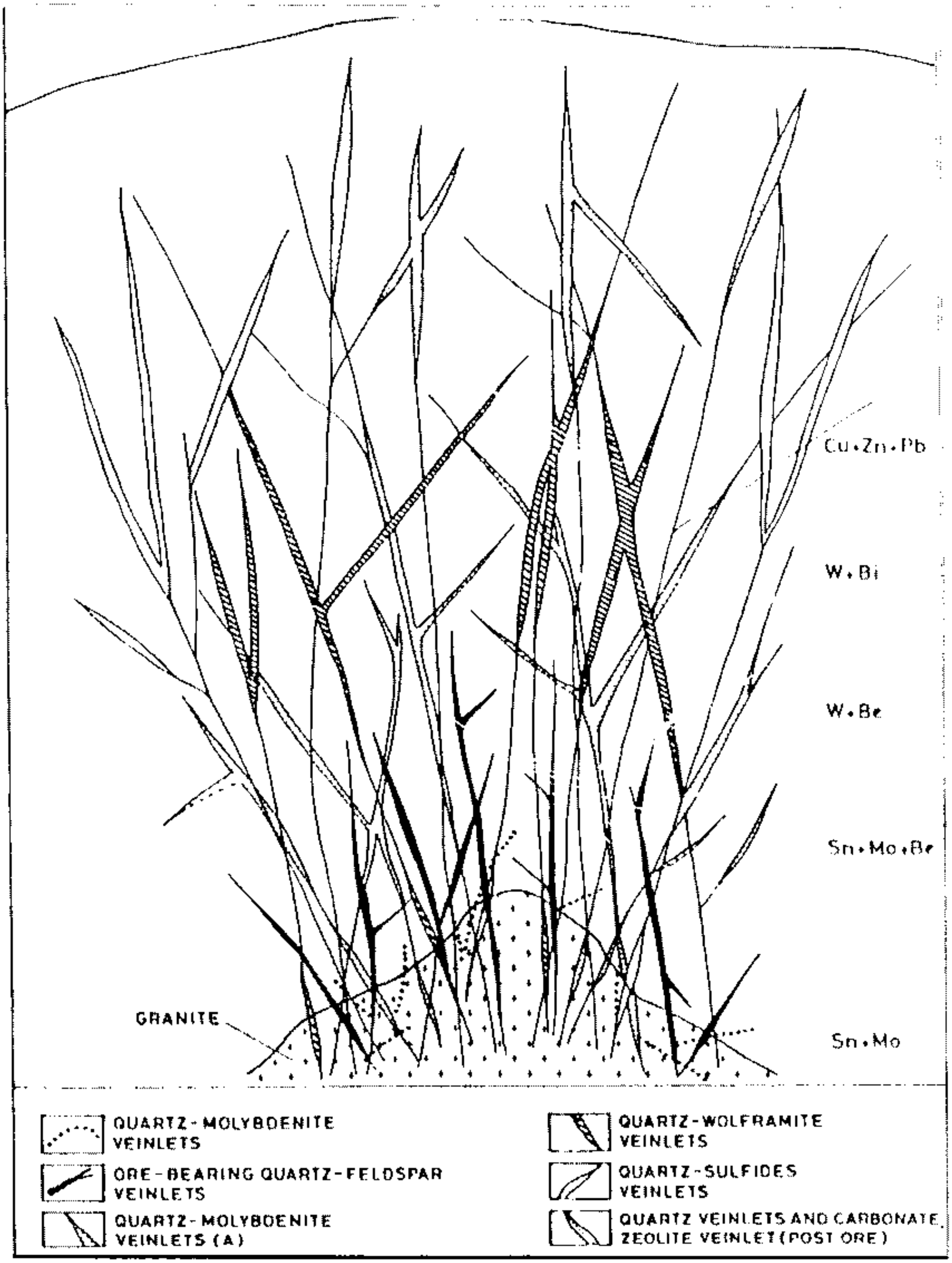



**Figure 18.** Spatail and temporal aspects of different generation of veinletsj above an intrusive in Kazakhstan (after Shcherba, 1970), from R.G.Taylor (1979): Geology of Tin Deposits, Elsevier, Amstecdam.

As a definition, Helgeson has suggested that "hydrothermal solutions are concentrated, weakly dissociated, alkali chloride-rich electrolyte solutions" (which is somewhat more definitive than that of mere "hot water". With the high chloride content of hydrothermal solutions and the presence of $H^+$ ions, it has been expected that such solutions would be highly acidic. This depends, however, upon the degree of dissociation of HCl into $H^+$ and $Cl^-$ ions. At temperatures of 100°C and less, HCl is almost completely dissociated and the pH is consequently low.

Hydrothermal solutions give rise to high-temperature hydrothermal doposits nearest the intrusive, intermediate-temperature deposits at some didistance outward, and low-temperature deposits father outward. Lindgren has designated these three groups as hypothermal, mesothermal, and epithermal deposits, according to the temperature, pressures, and geologic relations under which they were formed as indicated by the contained minerals. Lindgren's temperature ranges, however, are now believed to be too low, especially font the hypothermal deposits that evidently have reached 600°C and possibly even higher. Butte, Montana, and Bingham, Utah, minerals exhibit evidence of such temperatures illustrates the isotherms at the Wairakei geothermal area with a narrow conduit, wider spread temperatures near the surface and flow lines of the water.

Deposits formed by solutions that migrate far from the intrusive, or possibly are not derived from the intrusion at all, may approach the temperature of the host rock.They generally produce only weak reactions and are referred to as telethermal deposits. Some would include the Mississippi-type deposits in this category. On the other hand, near surface solutions that are under high initial pressure and high initial temperature would result in rapid reactions and rapid deposition of an unusual variety of minerals. Such deposits are named xenothermal as suggested by Buddington. Xenothermal deposits may exhibit hypothermal to epithermal mineralogy but in overlapping or telescopic configuration.

In their journey through the rocks, the hydrothermal solutions may lose their mineral content by deposition in the various kinds of openings in the rocks, to form cavity-filling deposits, or by metasomatic replacement of the rocks to form replacement deposits.The filling of openings by precipitation may at the same time be accompanied by some replacement of the walls of the openings. Thus there mat be a gradation between these two types of mineral deposits. In general, in favourable host rocks, replacement dominates under the conditions of high temperature and pressures nearer the intrusive where hydrothermal deposits are formed and cavity filling dominates under the conditions of low temperature and pressures where the epithermal deposits are formed; both are characteristic of the mesothermal zone (Figures 17, 18).

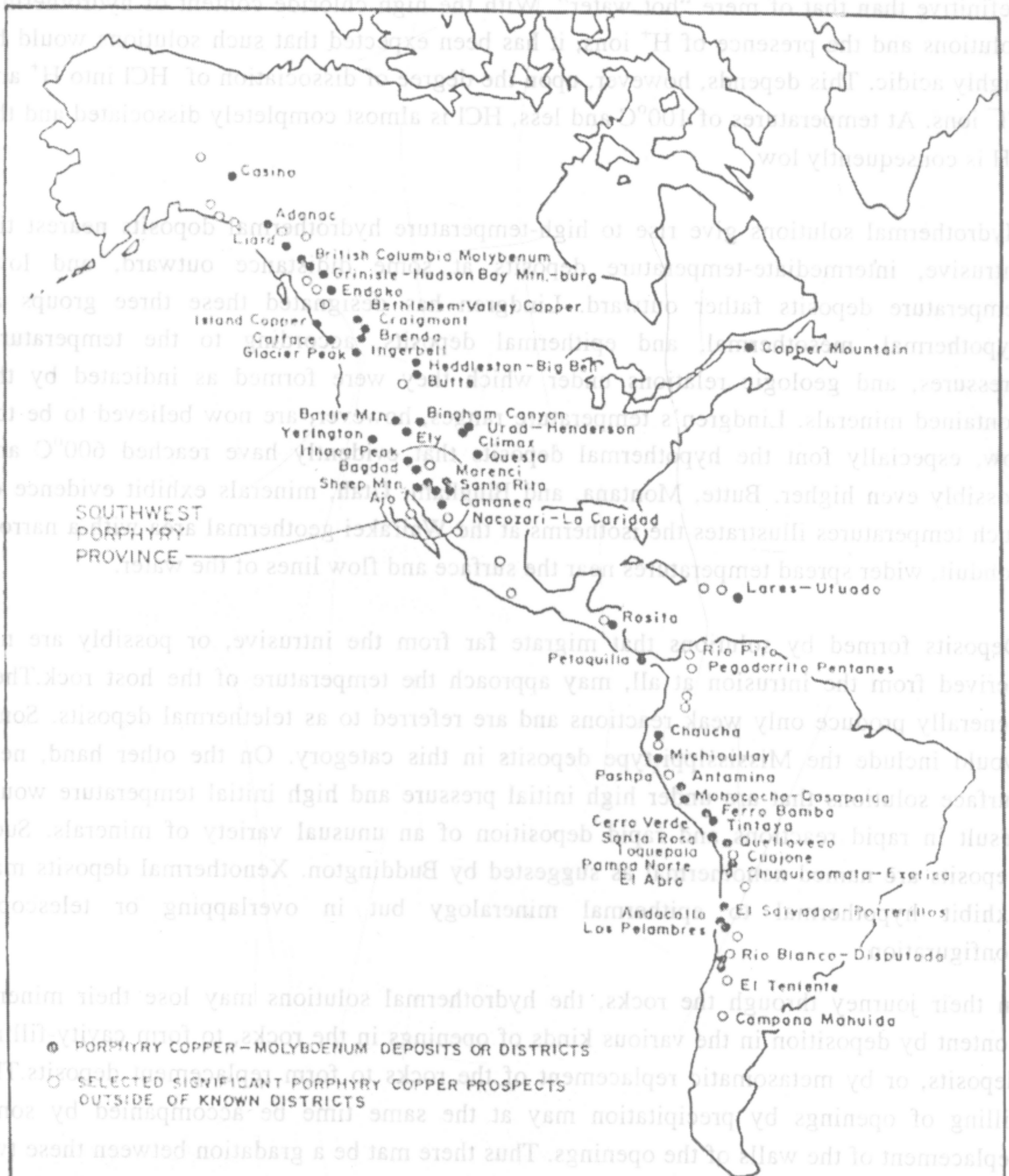



**Figure 19.** Distribution of porphyry deposits in North and South America (after Paul Eimon).

For convenience, the deposits resulting from cavity filling may be grouped as follows; discussions of each follow in sequence (Figures 17, 18, 20).

**I) Principles of hydrothermal processes**

Geologists attribute to hydrothermal processes. That vast array of metallic minral deposits that supply part of our useful metals and minerals. From such deposits are won most of the gold and silver, copper, lead and zinc, mercury, antimony and many non-metallic minerals. Consequently, it is these deposits that have been mined, investigated, and written about far more than any other group. They have given rise to many of the great mining districts of the world; part of the lore of mining sparing from them.

Essentials for the formation of hydrothermal deposits are: 1) available mineralizing solutions capable of dissolving and transporting mineral matter, 2) available openings in rocks through which the solutions may be channeled, 3) available sites for the deposition of the mineral content, 4) chemical reactions that result in depositition, and 5) sufficient concentrations of deposited mineral matter to constitute workable deposits.

**II) Resulting mineral deposits**

The process of cavity filling has given rise to a vast number of mineral deposits of diverse form and size, and such deposits have yielded a great assemblage of metals and mineral products. Much of the literature on economic geology relates to them.

1. Fissure veins.
2. Shear-zone deposits.
3. Stockworks.
4. Saddle reefs.
5. Ladder veins.
6. Pitches and flats; fold cracks.
7. Breccia-filling deposits: volcanic, collapse, and tectonic.
8. Solution cavity fillings: cave, channel, and gash veins.
9. Pore- space fillings.
10. Vesicufar fillings.

**III) Replacement mineral deposits**

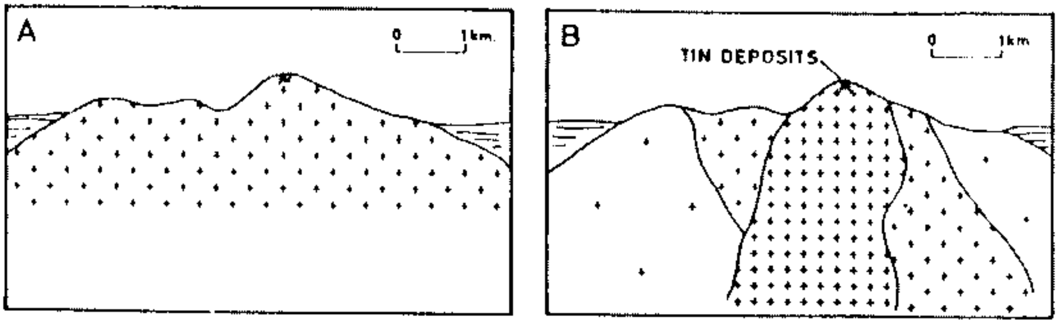
Mineral deposits formed by replacement may be divided into massive, replacement lode, and disseminated deposits, except for deposits of all metallic mineral deposits.

***Massive deposits.*** Massive deposits are characterized by great variations in size and extremely irregular form. Bodies in limestone generally thicken and thin, display wavy outlines, and ramify irregularly in all directions. Others are great irregular massive bodies whose larger dimensions may be measured in thousands of meters. Generally, the deposits consists mostly or entirely of introduced ore and gangue minerals, and included rock matter constitutes consist of stupendous masses of pure yellow sulfides, such as Rio Tinto, more than 600 ore-bodies into the rocks at Tinto.

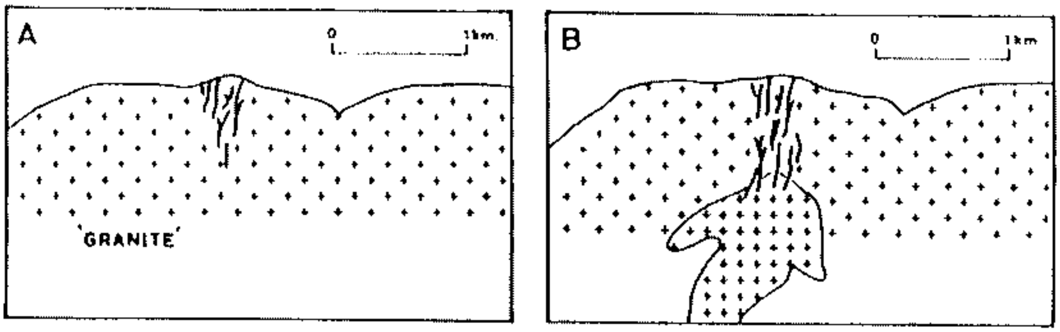
***Replacement lode deposits.*** Replacement lode deposits are localized along thin beds or fissures whose walls have been replaced. Consequently, they resemble fissure veins in form. Many so-called fissure veins are actually replacement lodes. In general, they are wider than fissure veins, and the width varies greatly along a single lode; it may range from a few centimeters to several tens of meters. The walls are commonly wavy, irregular, and gradational into the country rock. The ore may be massive or irregularly scattered in the rock. The gold veins of Kirkland Lake, Ontario; the copper veins of Kennecott, Alaska; and the lead veins of the Coeur d'Alene, Jdaho, are examples.

***Disseminated replacement deposits.*** In disseminated replacement deposits, the introduced material constitutes only a small proportion of the ore.The ore minerals are peppered through the host rock in the form of specks, grains, or blebs, generally accompanied by small veinlets, and represent the multiple-center types of replacement. The ore consists of altered host rock and the disseminated ore grains. The ores are mostly low grade. The boundaries are vague; the metallized part fades into waste rock, and the ore limits are determined by the workable grade of the ore (Figure 19).

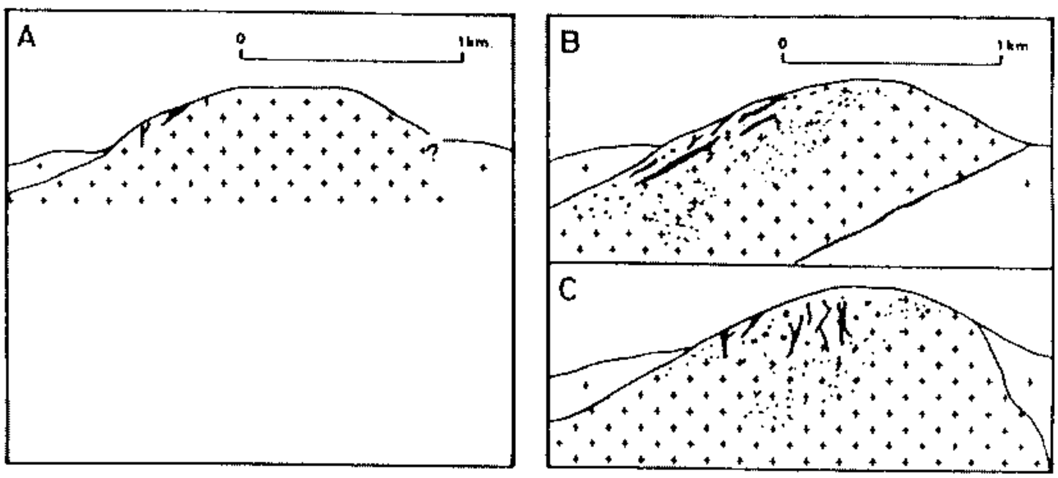
Disseminated replacement deposits are generally huge, which permits large-scale mining operations and the utilization of low-grade ores. A lowering of a workable-grade copper ore, for example by 0.25 percent, may in-crease the ore reserves by tens of millions of tons. The great "porphyry copper" deposits, many of which are mined from huge opens pits, fall in this group of deposits. Some idea of the enormous size of disseminated deposits and the immensity of the operations may be realized from the following examples: The Chile copper Co. Mine at Chuquicamata is reported to have reserves of more than 1 billion tons of copper ore, which to date has averaged 1.10 percent copper . The great Utah Copper mine at Bingham, Utah, has officially reported reserves of 600 million tons of ore containing about 0.65 percent copper, although known reserves and grade are now higher and lower respectively. It has treated over 125,000 tons of ore per day. More than 1 billion tons of waste have been mined from the Bingham Canyon Open pit. The Zambian copper belt has estimated reserves of 900 million tons, averaging 3,5 percent copper. The Climax molybdenum mine at Climax, Colorado, has ore reserves of over 500 million tons averaging about 0,24 percent molybdenum and has produced more than $10^9$ pounds of contained molybdenum.




Tin bearing granitoids initially assumed homogeneous
(A) are subsequently shown to be multiphase (B).




A tin bearing granitoid? (A) is subsequently shown to
be the host to the true parent (B).




Even when a tin bearing granite is clearly outline (A),
the tin distributions may be anisotropic, varying both laterally and hozitally

**Figure 20.** Problems relating to sampling and interpretation of data relating to geochemical specialiasion of granitoids.

The Alaska Juneau gold mine handled 12,000 tons of ore per day which averaged about 0.035 ounce ($1.23 at $35 per ounce) of gold per ton and has mined around 88 million tons yielding about $81 million from ore averaging 0.043 ounces of gold per ton. Another example of ores and deposits that belong to this group is the disseminated lead deposits of southeastern Missouri with the greatly increased reserves of the Viburn belt.

Form and size: The form of replacement deposits is determined largely by the structural and sedimentary features that localize them. Accordingly, they are irregular, blanket-shaped, tabular, pipe-shaped, synclinal, or anticlinal, or they may be large irregular disseminated deposits.

## VOCABULARY

| | |
|---|---|
| Operating just outside of the | Xảy ra ở ngoài... |
| Variaty of hydrothermal solution | Tính muôn vẻ của dung dịch nhiệt dịch |
| Mineralizing solution | Dung dịch khoáng hoá |
| Epigenetic deposits | Các mỏ hậu sinh |
| Connate | Nguyên sinh, thâm sinh |
| To mingle | Trộn lẫn, lẫn vào |
| Have been heated | Được đốt nóng |
| Isotopic (adj) | Đồng vị |
| Hitherto (adverb) | Cho tới nay |
| Fluid inclution | Bao thể lỏng |
| Trace amount of | Một lượng rất nhỏ/vết |
| Alkali chloride-rich electrolide solution | Dung dịch điện phân giàu clorua |
| Have been expected | Có khả năng, chắc rằng |
| Degry of dissociation | Mức độ phân huỷ/phân ly |
| Togive rise to | Gây ra, tạo thành |
| Hypothermal deposit | Mỏ nhiệt dịch nhiệt độ cao |
| Mesothermal deposit | Mỏ nhiệt dịch nhiệt độ trung bình |
| Telethermal deposit | Mỏ viễn nhiệt |
| Epithermal deposit | Mỏ nhiệt dịch nhiệt độ thấp |
| Xenothermal deposit | Mỏ nhiệt dịch ngoại lai |
| Exhibit | Biểu hiện, biểu thị |
| Telescoping | Chồng nhau, lồng nhau |

| | |
|---|---|
| Openings | Khe nứt, lỗ hổng |
| To conduct heat away | Truyền nhiệt đi xa |
| Straigh-walled open fissure | Khe nứt mở, vách thẳng |
| Intricate (adj) | Phức tạp |
| Constricted (adj) | Hẹp lại, thắt nhỏ lại |
| In causing & localizing the deposition | Gây ra sự lắng đọng |
| To be initiated | Được bắt đầu, khởi đầu |
| Prevail (adj) | Chiếm ưu thế, phổ biến |
| To promote | Tăng cường, đẩy mạnh |
| Channel way | Kênh dẫn |
| Supercritical stream | Dòng trên tới hạn, dòng bão hoà |
| Solubility | Độ hoà tan, tính hoà tan |
| Fissure vein | Mạch khe nứt |
| Shear-zone deposit | Mỏ trong đới phá huỷ kiến tạo |
| Stockworks | Mạch xâm nhiễm |
| Saddle reef | Mạch yên ngựa |
| Ladder veins | Mạch bậc thang |
| Pitches and flats; fold crack | Mạch dốc & nằm ngang; mạch uốn nếp |
| Pore- space fillings | Lấp đầy lỗ hổng |
| Vesicufar fillings | Lấp đầy dạng bọt |

## III.4. WALL ROCK ALTERATION

If wall rocks are unstable in the presence of hydrotermal ore-forming solutions, both will undergo physical and chemical changes to reach equilibrium. The resulting wall-rock alteration may be subtle, such as the incipent hydration of selected ferromagnesian minerals; or it may be clear-cut, as in the silisification of limestone. The alteration may range from simple recrystallization to the addition, removal, or rearrangementof chemical components. It may take place in advance of emplacement of the ore minerals or during any part of hydrothermal activity.

The nature of wall-rock alteration by hydrothermal processes offers strong evidence in support of the view that many hydrothermal solutions are neutral or slightly acidic at higher temperatures. Helgeson (1964) states that hydrothermal alteration of aluminosilicate rocks is essentially aprocess of trading $H^+$ ions for other cations in the rock. The fundamental contols include any processes that affect the activities of reacting constituents in solution.

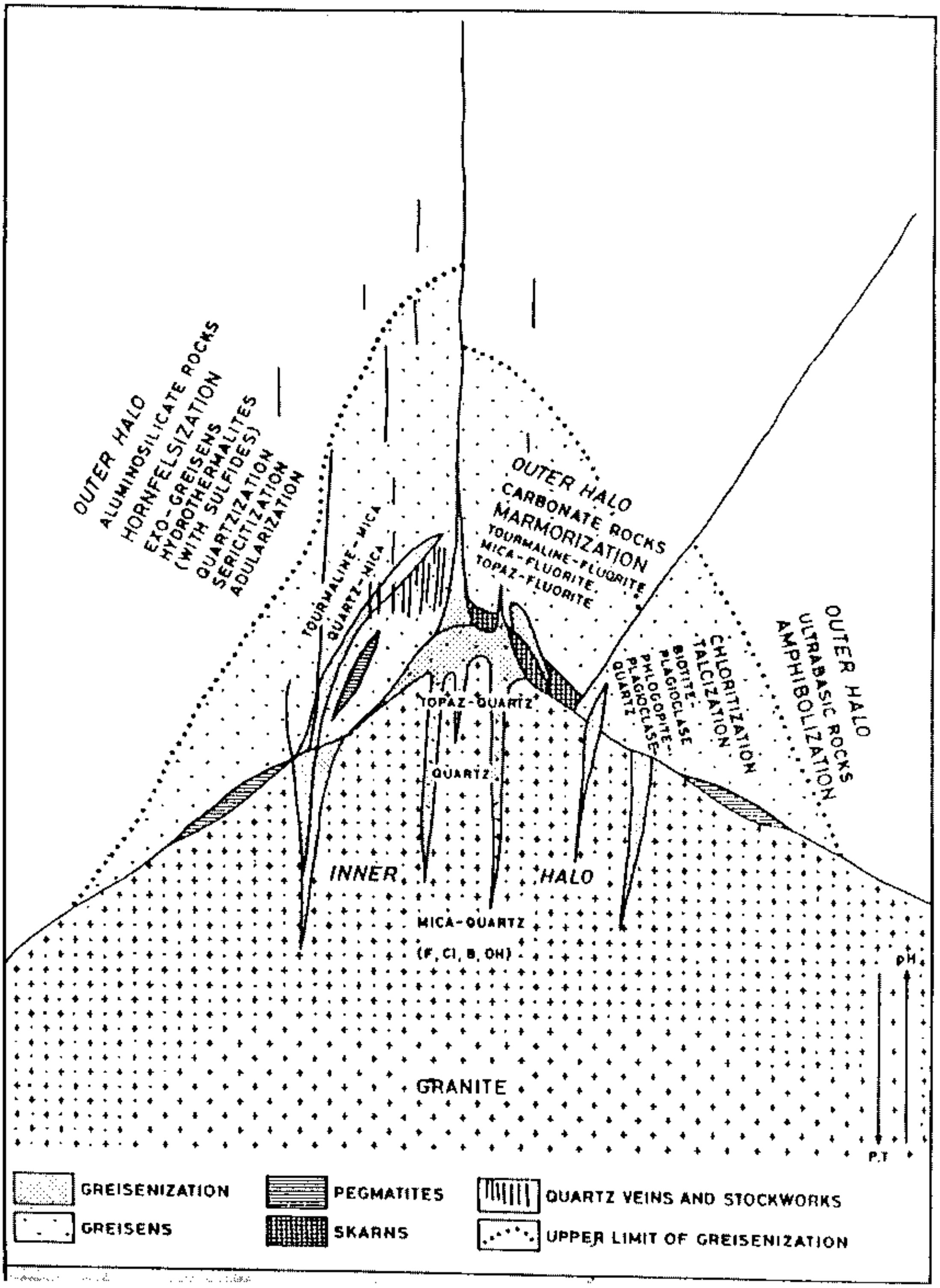



**Figure 21.** Wall-rocks alterations in aluminosilicate, carbonate and ultrabasic environments.

Hemley and Jones (1964) list as the most significant controls: 1) the compositional nature of the wall-rock, 2) changes in the pressure-temperature state of the aqueous phase, such as by boiling, with possible fractionation of volatile components, 3) mixing of hypogene solutions with supergene solutions or groundwaters, and 4)oxdation of $H_2S$ to strong sulfur-species acids (Figure 21).

Wall-rock alteration may bring about recystallization, changes in permeability, and changes in color. Carbonate rocks are characteristically recrystallized along the borders of a vein or near an igneous contact. Color changes include bleaching, darkening, and the development of aureoles of various colors. Pastel colors of micas and clays are especially prominent around some ore deposits and may form conspicuous leads to ore. Clay minerals are generally white or light shades of green, brown, and gray, so argillization may produce a noticeable bleaching effect; even a black basalt may be altered to a white or light-green body of clays and other hydrous minerals. Similarl, the formation of chlorite or epidote produces a green color. Silification, carbonatization, and hydration are typical of the processes that take place in alteration zones-and they may all operate simultaneously, Although generalizations are hazardous because the possibilities are too diverse, certain reactions in specific environments can be expected. For example, water is usually added to the alteration zone, except where the rocks are completely replaced by silica, and carbon dioxide is generally removed from carbonate host rocks. Furthermore, certain minerals can be routinely and repetitively expected in alteration assemblages such as potassic, propylitic, phyllic, argillic, advanced argillic, and skarm (Figure 21).

Conditions of temperature and composition usually differ at various distances from a fissure or conduit so that different types of alteration can be produced simultaneously in adjcent volume (Hemley, 1959) product kaolinite at the Spruce Pine deposit just mentioned.

## VOCABULARY

| | |
|---|---|
| Wall rocks | Đá vây quanh |
| Hydrothermal ore- forming solution | Dung dịch nhiệt dịch chứa quặng |
| To reach equilibrium | Đạt tới trạng thái cân bằng |
| Wall-rock alteration | Sự biến đổi đổi đá vây quanh |
| Incipient hydration | Sự hydrat hóa sớm (thời kỳ sớm) |
| Silicification | Sự silic hóa |
| Rearrangement of chemical components | Tái phân bố (sắp xếp lại) các thành phần hóa học |
| Hydrothermal activity | Hoạt động nhiệt dịch |
| In support of the view | Ủng hộ quan điểm |
| ... neutral or slightly acidic at higher temperature | ... ở nhiệt độ cao là dung dịch trung hoà hay axit yếu |
| Aqueous phase | Pha lỏng |
| Volatile components | Các thành phần chất bốc (dễ bay) |
| Hypogene | Thâm sinh (có nguồn gốc sâu) |
| Supervene | Biểu sinh (có nguồn gốc ngoại sinh) |
| Groundwater | Nước dưới đất |
| Igneous contact | Tiếp xúc với đá xâm nhập |
| Bleaching | Sự mất màu (tẩy trắng) |
| Aureoles of various colours | Vành phân tán nhiều màu |
| Pastel colours | Màu phấn |
| A noticeable bleaching effect | Hiệu ứng mất màu có thể nhìn thấy (có thể quan sát được) |

# CHAPTER FOUR: EXOGENETIC MINERAL DEPOSITS

## IV.5. PLACER DEPOSITS

Resistate minerals, those that are chemically stable or metastable in the weathered zone of the Earth's surface and are not decomposed by weathering orocesses as the surrounding rocks are dissolved or disintegrated, either remain in the soil or are carried away by rain, streams, waves, or wind. The lighter particles of some resistates are readily moved and become dispersed; more brittle ones break easily along cleavage or fracture planes and become so fine-grained that they, too, are dispersed. But heavy, stable, durable minerals left as residual particles in soil may be washed into drain-ages. Where the slopes below the outcrops are steep, or where other conditions encourage movement, the resistant particles slide, creep, or are washed gradually down the slope until they reach a stream bed. In streams, they are separated from finer grained, hydraullcally lighter clay- and silt-sized materials that are washed downstream. The heavy minerals may then be concentrated into the sands and gravels of streams and beaches. The process of elutriation, or separation by agitation of minerals moving in aqueous suspension in streams or at beaches, causes heavy particles to to settle to the bottom with the removal of the lighter or more brittle, finer grained gangue. The result is a concentration of the heavy, tough, and chemically resistant minerals. These minerals may accumulate near the outcrops as residual concentrations; they may be washed into streams and accumulate in sand bars or in riffles and irregularities along the channel doors; or they may reach bodies of water where are reworked by wave action and deposited in beach sands. Moving waters sort them according to their specific gravities, their shapes, their pickup velocities, the velocity of flow, bottom gradients, and other factors. Minerals with properties favourable for deposition are concentrated at the expense of lighter, brittle particles, which are broken, scattered, and transported into the deeper basins of deposition. Sutheriand (1982) showed that longshore transport of diamonds reduces average grain size but improves quality because inferior stones are destroyed. The mere presence of gem diamond is commonly enough to define an orebocdy: hydraulic concentration is ineffective because the specific gravity of diamond is only 3.5.

The most common and abundant placer minerals are the native metals, especially gold and the platinum group, and many of the heavy "inert" oxides, silicates, and other phases such as cassiterite, chromite, wolframite, rutile, magnetite, ilmenite, zircon, and many gemstones. Since sulfides readily break up and decompose in modern oxygenated environments, they seldom accumulate in placers. In a few exceptional instances, however, small amounts of relatively insoluble sulfides for example, the cinnabar at New Almaden, California have been recovered from geologically young placers formed near a lode deposit. Magnetite and ilmenite are among the most abundant minerals in placers, but fluvial concentrations of these are rarely sufficiently rich to be of economic interest. Magnetite or "blach sand" behavior in stream meanders, rapids, and confluences can be studied casually in most of the mountain streams of the world. Some of the world's greatest tin and diamond deposits are placers; examples are the cassiterite-rutile residual and river placer deposits of Nigeria and the diamond gravels of the Vaal and Orange rivers in the Republic of South Africa (Figure 22).

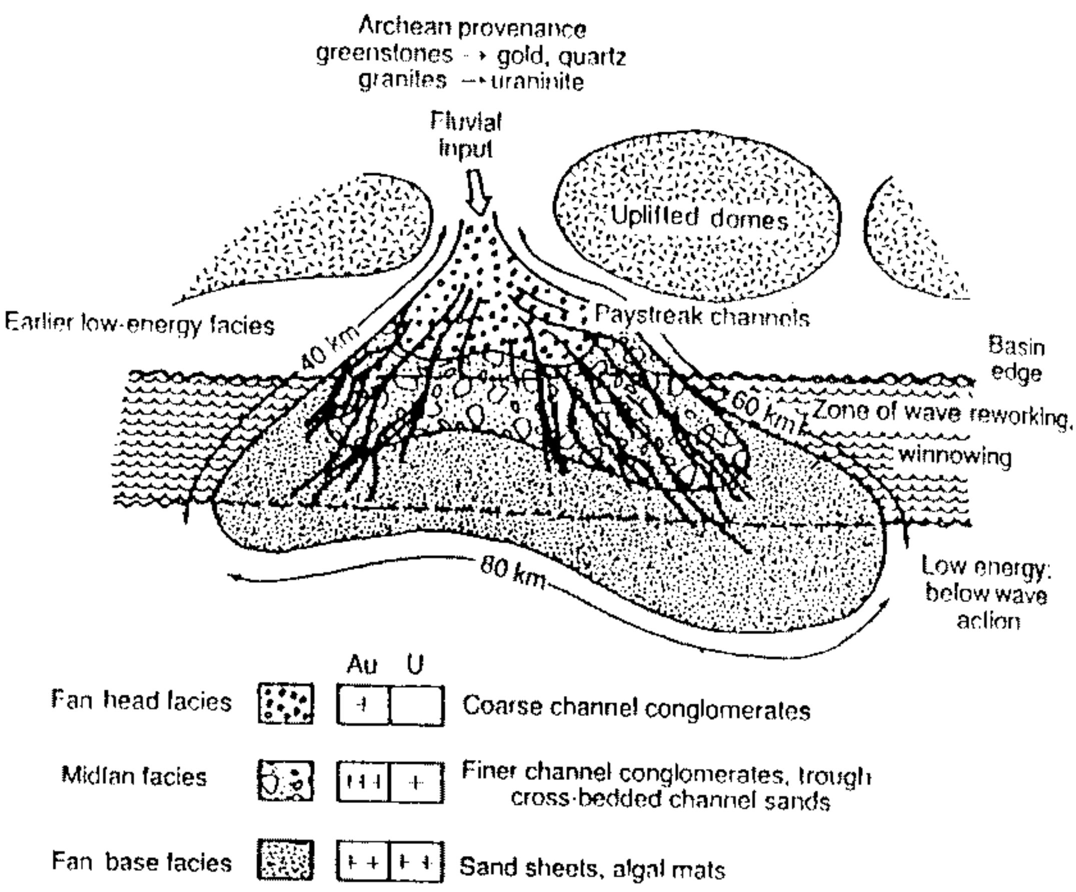



**Figure 22.** Conceptual model of Proterozoic Witwatersrand goldfield as a fluvial fan developed at the mouth of a major river (after Pretoris, 1981).

But the world's most valuable placer commodity is gold. Placer gold varies widely in composition, depending on the character of the original mineral and the distance from the source lode to the placer resting place. Native gold in veins is generally alloyed with silver, less commonly with copper and other metals. Because both silver and copper are oxidizable and more water-soluble than gold, those metals are selectively leached from electrum during weathering, erosion, and downstream transport (Figure 22). Consequently, gold far removed from its source tends to become puer than the original material (Desborough, 1970). The constant pounding and abrasion that particles of placer gold receive as they travel downstream also result in a gradual reduction in grain size away from the lode. The malleability of gold leads to the production of colours, tiny thin flakes of gold that may actually float on water and that reflect brighter glints of light than their small mass would suggest. Incidentally, a tantalizing problem that deserves study is that of nugget formation. Few base- or precious metal deposits contain gold as coarse as the nugget that appear to be derived from them. How did the 6.2 kg nugget resently found in Brazil form?

Placer deposits have been divided into eluvial, on hill slopes; alluvial on fans; fluvial in streams; lacustrine in lakes; glacial and marine (Bilibin, 1938 - Principles of Placer Geology).

## VOCABULARY

| | |
|---|---|
| Placer deposits | Các mỏ sa khoáng |
| Resistant minerals | Các khoáng vật bền vững |
| Weathered zone | Đới phong hóa |
| Weathering process | Quá trình phong hóa |
| Lighter particles | Các hợp phần nhẹ |
| To disperse | Phân tán |
| Along cleavage or fracture planes | Dọc mặt phiến hay khe nứt |
| Stable – durable minerals | Các khoáng vật bền vững |
| Residual particles | Các tổ phần sót (tàn dư) |
| To slide | Trượt |
| Agitation | Sự khuấy động |
| To creep | Bò |
| To be concentrated into ... | Được tích tụ trong |
| Elutriation | Sự chọn lọc, quá trình chọn lọc |
| To settle to the bottom | Lắng đọng ở đáy |
| To be washed downstream | Được rửa, đãi xuôi dòng (theo dòng) |
| To be washed into | Bị cuốn theo, bị đãi thành |

| | |
|---|---|
| To sort them according to their specific gravitates, their shapes, ... | Chọn lọc khoáng vật theo tỷ trọng, hình dạng, ... |
| Basins of deposition | Các bồn trầm tích |
| To be reworked by wave action | Bị tái sàng lọc bởi hoạt động sóng |
| Riffles | Máng dãi |
| Hydraulic concentration | Lắng đọng thủy lực |
| Native metals | Các kim loại tự sinh |
| Gemstones | Đá quý |
| Sulphides | Sunfua kim loại |
| Oxygenated environment | Môi trường oxy hóa |
| Lode deposit | Mỏ mạch |
| Relative insoluble sulphides | Các sunfua ít hoà tan |
| Fluvial concentration | Tích tụ do sông, do sông tạo nên |
| Stream meanders | Khúc uốn của sông |
| Rapid | Thác, ghềnh |
| Confluence | Ngã ba hoặc ngã tư sông (suối) |
| To be alloyed with ... | Được hợp kim với ... |
| To be oxydizable | Có thể bị oxy hóa |
| To be leached from | Bị (được) rửa lũa từ |
| Abrasion | Sự mài mòn |
| Erosion | Sự xâm thực |
| Malleability | Tính dễ dát mỏng |
| Tinge thin flake of gold | Vảy vàng rất nhỏ xíu |
| Glint (n, v) | Lóe sáng, lấp lánh |
| Native gold | Vàng tự sinh |
| To be alloyed with | Được hợp kim với |

## IV.6. WEATHERING AS AN ORE FORMING PROCESS

Weathering is the step-child of the Earth sciences. It is neglected by geologists, misunderstood by geographers, misused by pedologists and exploited by agronomists. Geologists usually work from the hard Earth's core towards the surface and stop at the first signs of weathering, geographers study the surface forms and there origin but too often forget to look at the underlying rocks, pedologists and agronomists seldom reach deeper than the firsts few metres. Civil engineers have most contact with the weathering mantle, that troublesome and untrustworthy but ubiquitous layer between surface and good strong footing for their structures and buildings.

Still, weathering as a process and the weathering mantle as a zone in the earth crust are of greatest importance to human society and life: it is not only the base of most of our food requirements, it also contains the largest and economically most important deposits of industrial minerals and rocks such as clay, sand and gravel. Furthermore, iron, manganese and aluminium deposits and much of the copper, nickel and tin used in industry, have been formed or concentrated in the weathering zone.

Weathering is the surface and near-surface process of physical disintergration and chemical decomposition of rock that produces an in-situmantle of waste. It is synonymous with supergene alteration, specifically excluding alteration through the action of hydrothermal solutions.

Chemical weathering is the process by which atmospheric, hydrospheric and biological agencies act upon and react with the mineral constituents of rock within the zone of influence of the atmosphere, producing relatively more stable, new mineral phases (after Reiche and Loughan). It can be considered as a re-equilibration of the mineral phases of rocks with P and T as reigning at the surface, and an abundance of water, $CO_2$ and organic.

Mechanical weathering includes the destructive processes of temperature, pressure release following denudation, frost action in rock fissures, water and saline solutions in fissures and intra-crystalline pores, ets.

Weathering processes are very much climate related: in the higher latitudes and in deserts mechanical weathering predominates, while in lower latitudes -in particular in the more humid and warm regions-chemical weathering determines the face of the Earth. Also, higher ambient temperatures in lower latitudes will considerably increase the speed of the chemical weathering processes.

Chemical weathering is most important for the formation of a number of mineral deposits. Under average condition - in a humid and warm climate - and on an intermediate to acidic country rock (in this context called "parent rock") a saprolitic weathering mantle is formed composed of, from the parent rock upward, rotten rock, structured saprolite, unstructured saprolite, accumulation zone, and residual soil.

The processes involved are imprecisely known, but in general they include hydrolysis, oxidation, simple and incongruent solution, formation and precipitation of new minerals, and transport of matter in watery solutions. Not all minerals are, however, readily destructed by chemical weathering: the more weathering-resistant minerals are residually accumulated in the top layers of the weathering profile. Roughly, the weatherability of the common rock forming minerals is related to the Bowen order of crystallization: the earlier the mineral is formed the more readily it is attacked by weathering. Note, however, that many early crystallizing accessory minerals are highly weathering-resistant: zircon, rutile, chromite, diamond, ets.

The speed of the weathering processes is unknown, but as climate is important, it can be deduced that during the Cainozoic, with its even more frequent and stronger changes in climate (ice ages!), strong weathering and strong mechanical erosion and denudation must have alternated. As a result many of the related mineral deposits are poly-phase.

## VOCABULARY

| | |
|---|---|
| Step-child of | Đứa con đầu lòng của, sản phẩm đầu tiên của |
| To be neglected | Bị coi thường, bị bỏ qua |
| To be misused by | Bị lạm dụng bởi |
| Penologists | Các nhà thổ nhưỡng |
| Agronomists | Các nhà nông học, kỹ sư nông nghiệp |
| Civil engineer | Các kỹ sư xây dựng |
| Untrustworthy (adj) | Không tin cậy, không tin tưởng |
| Ubiquitous (adj) | Ở đâu cũng có, có mặt khắp nơi |
| Weathering mantle | Vỏ phong hóa |
| Weathering zone | Đới phong hóa |
| Disintegration | Sự phân hủy |
| Decomposition | Sự phân hủy, phân ly, phân tích |
| In-situ mantle of | Lớp vỏ tại chỗ của ... |
| Mechanical weathering | Phong hóa cơ học |
| Chemical weathering | Phong hóa học |
| Denudation | Sự bào mòn, quá trình bóc mòn |
| Frost action | Tác dụng băng giá |
| Saline solution | Dung dịch muối |
| Fissures | Các khe nứt |
| Infra-crystalline pores | Các lỗ hổng trong tinh thể |

| | |
|---|---|
| Saprolitic weathering mantle | Vỏ phong hóa saprolit |
| Parent rock | Đá gốc |
| Simple & incongruent solution | Dung dịch đơn & dung dịch phức |
| Formation & precipitation of new minerals | Sự thành tạo và sự lắng đọng các khoáng vật mới |
| Weathering-resistant minerals | Các khoáng vật bền vững trong điều kiện phong hóa |
| Weathering profile | Mặt cắt (trắc diện) phong hóa |
| Weatherability | Mức độ phong hóa, khả năng phong hóa |
| Bowen order of crystallization | Dãy hay thứ tự kết ting khoáng vật của Bo-uên |

## IV.7. SEDIMENT - HOSTED MINERAL DEPOSITS

Sediments host the most valuable mineral resources of mankind: hydrocarbons, coal and water. Metal explorationists to have always had a keen interest in special sedimentary environments, e. g. platform carbonates hosting important Pb, Zn - deposits.

North Amercan geologists have traditionally viewed economic geology as synonymous with the study of hydrothermal deposits: all deposits, even those formed at obviously low temperatures were relatted to some distant hypothetical igneous activity. More recently, the importance of sedimentary processes in ore genesis has begun to be appreciated: Mineral deposits have to be treated within the context of the surrounding sediments. Metal explorationists, frequently with a 'hard rock' background need to study fundamental sedimentary processes-i. e.basin development- to fully appreciate the mineral potential of sedimentary environments. A lot can be learned from hydrocarbon research carried out by the big transnational oil companies.

### I. Mineral deposits hosted by clastic sediments

This ore deposit environment is composed of transported weathering products, both particulate and preccipitated from solutions. The transport distance may vary from a few hundred metres to many hundreds of kilometres, the coarser material generally travelling shorter distances than the finer, while the provenance of metal - carrying solutions is frequently difficult to establish. Also, the longer the travelling distance of the material making up the sediment, the more chance there is for maxing with material from other derivations, such as volcanic tuff, ash, and emanations, or material of organic origin such as carbonate and silicate skelletons etc. Further, rotting organic material from local origin may produce a reducing environment in a sediment that causes the precipitation of sulphides from percolating solutions, e. g. marcasite in many placer deposits.

Econmic meneral acumulations in clastic sediments can be divided into two non - related subgroups:

1) Deposits formed by mechanical accumulation of generally heavy, weathering - resistant particles liberated during weathering and concentrated by moving water: placers.

2) Deposits formed by solutions either derived from the weathered hinterland or from the sedimentary basin itself.

The later subgroup occurs in clastic sediments of highly varying grain size (pebble- gravel- sand - silt - clay) and in highly varying sedimentary environments (terrestrial to shallow marine, ± evaporite basin to full marine) resulting in several deposit types.

The timing of the introduction of the metals into the sediments is also strongly variable. It is therefor useful to take a closer look at a few related genetic terms:

# **Syngenetic**: Deposition of sulphides simultaneous with the host rock clastic grains;

# **Diagenetic**: Post-depositional equilibrium reaction between clastic rock particles, air, ground water, organic decay products, and possibly matter transported upward from the deeper parts of the sedimentary basin;

# **Epigenetic**: Post- depositional and post - diagenetic, hence the reactions take place between the total, more or less consolidated, original rock with matter introduced from outside sources.

## II. Mineral deposits hosted by chemical sediments

The economic mineral deposits of this section are mainly deposits of iron and manganese. The majority is of Precambrian age, in particular between 2,600 and 1,800 Ma old, and are of the banded iron formation or BIF type. The iron content (may be quoted as $Fe_2O_3$ and FeO, or as total Fe) varies between 25 and 40% Fe. Other main components are $SiO_2$, and $CO_2$, and locally manganese, while $Al_2O_3$, MgO, CaO, alkalies generally are below 2 or even 1% each.

This pureness, the finely laminated nature, and the continuity of this lamination over very large distances - up to thousands of km - suggests their origin as chemical or biochemical precipitates in extended bodies of water, sufficiently deep to prenvent any wave action on the precipitate.

There is considerable speculation on the origin in detail; an interesting hypothesis by Lepp & Goldich (1964, Econ. Geol., 59, 1025 - 1060) lets the iron and silica derive from a weathering continental surface at the time that the free oxygen content of the atmosphere was still nil or very low. A lateritic type weathering would largely retain Al, ferric iron and phosporous, and also part of the silica, while ferrous iron and much of the silica would be transported by groudwater to the oceans - see chart below.

Later, at the time the atmosphere did contain free oxygen the weathering processes could produce somewhat different effluents, containing Ca and Mg, and the resulting precipitates are less pure Fe + Si

It should be realized that the original preccipitates were probably gels or amorphous, water - rich masses and colloidal particles. During early diagenesis these preccipitates change into discrete minerals such as quartz, hematite, etc.; these minerals will show only primary textures. Later, low - grade metamorphism changed the mineral composition and caused the appearance of metamorphic minerals with a secondary or replacement texture, such as stilpnomelane, minnesotaie, etc.,

*** Sedimentary iron deposits**

The average crustal abundance of iron is 4.7 mass %; iron occurs in most rocks of the earth's crust but the distribution is highly variable:

| | | | |
|---|---|---|---|
| Ultramafic rocks | 9.85% | Sandstone | 0.98 - 3.10% |
| Basic rocks | 8.56% | Carbonate | 0.38 - 1.30% |
| Granites | 5.85 - 2.70% | Sea water | 0.01% |
| Syenites | 3.67% | Average lithosphere | 4.65% |
| Shale | 3.33% | | |

There are two main rock types:

***Ironstone:*** - an iron - rich sedimentary rock, either deposited directly as a ferruginnous sediment of mixed clastic - chemical origin, or resulting from chemical replacement. The term is customarily applied to hard, coarsely banded or non - banded, and non - cherty sedimentary rocks of Phanerozoic age. They are often of oolitic texture, e.g. minette iron ore from Luxembourg and France.

***Iron-formation:*** - a general term for layered, bedded or laminated rocks that contain 15% (by mass) or more of iron, in which the Fe minerals are commonly interbanded with quartz, chert or carbonate, and where the banded structure industrial development, however, was closely related to much smaller iron deposits mostly of younger age, e. g. colitic ferruginous deposits, such as the Clinton ores the southeastern U.S.A. and the minette ores of the Alsace - Lorraine (Luxemburg, France), bog iron ores and iron carbonate beds called black band ores.

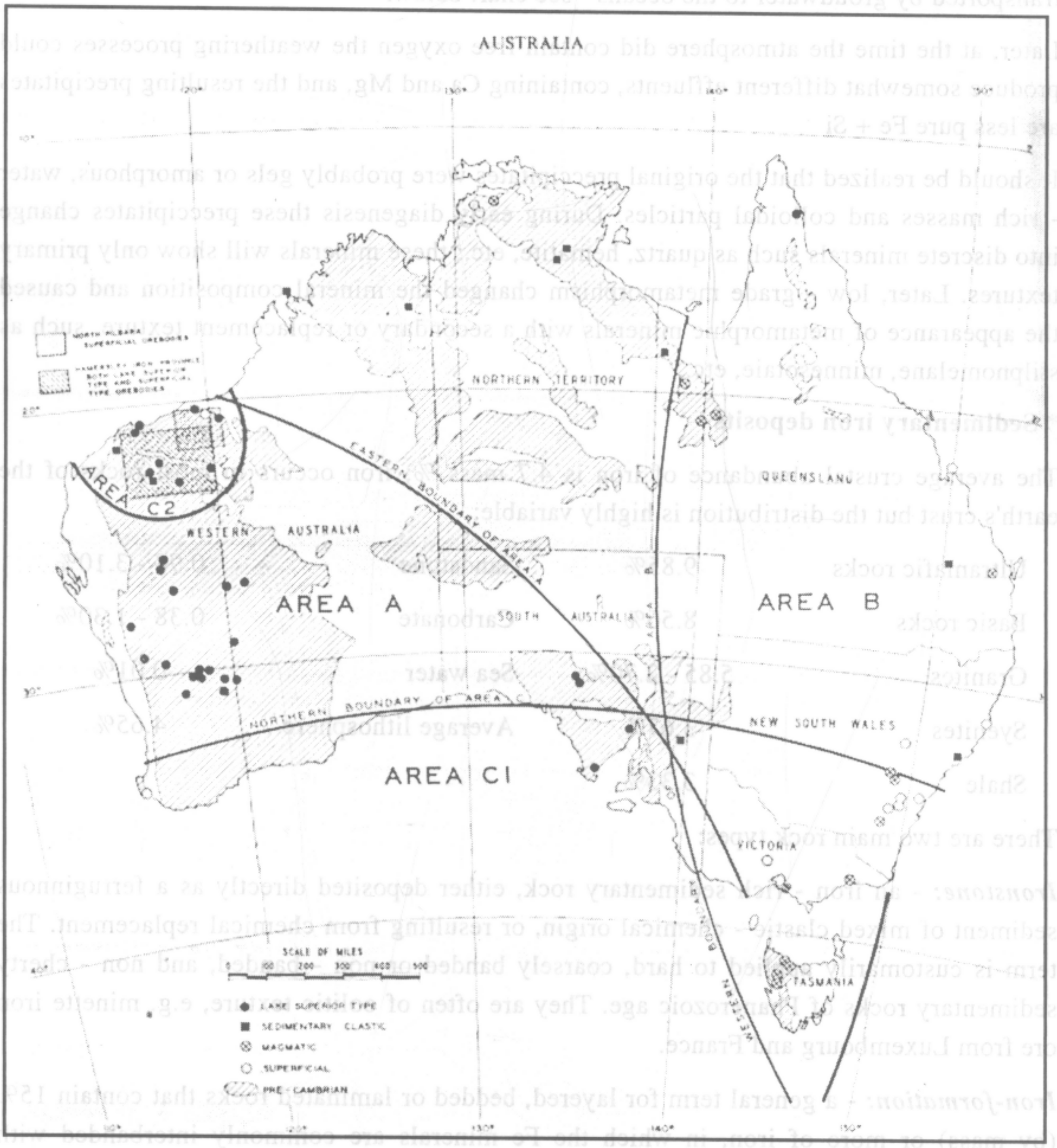



**Figure 23.** Distribution of iron ore deposits in Australia.

In modern times the economic importance of an iron deposit is generally a questions of grade against shipping distance. In the industrial centre of the U.S.A. the taconite with 20% Fe can be economically exploited.

Brazilian and Australian ores that are shipped to other continents need 50% or more Fe to be economic. This high grade can generally only be obtained through a natural process of seconday enrichment after the original formation. Tropical, lateritic weathering is the process that has enriched BIF deposits of Brasil, Liberia, Australia, etc. to grades that renders them economically exploitable (Figure 23).

The last quarter century tremendous of iron ore, mainly BIF, have been found (Ungave, Canada; Hammersley and others, Australia; Carajas, Brasil, etc.) reason why at present little exploration for Fe ores is going on. The above new finds were the result of aeromagnetic surveys and just chance encounters. Magnetic and gravity methods are most effective in prospecting.

*** Sedimentary manganese deposits**

Iron and manganese are rather similar in their habits and appearance in nature. Some iron formations have an appreciable Mn content (up to 7% in the Cuyuna iron formation deposit, Minnesota, U.A.S.) but usually it is in the range of 0.5 - 1.0%. This means that there are natural Weathering and other processes that work selectively on one of the two elements. In eastern Europe several large sedimentary Mn deposits occur; they can be devided in twotypes:

a. Quartz-glauconite sand-clay association, as found in the south Ukrainian Oligocene basin, with deposits in the Ukraine, Georgia and Bulgaria: the grades vary from a few per cent up to 35% Mn. The ores range from oxidic to carbonate in composition (Figure 24).

b. Manganiferous carbonate association, with the largest examples in Russia and in Morocco. The manganiferous limestone and dolomite range in grade from 5 - 30% Mn.

Manganese is mostly used as an additive in steel fabrication, and hence the manganese ores used for that purpose should be extremely low in steel contaminating elements such as phosporous and aluminium.

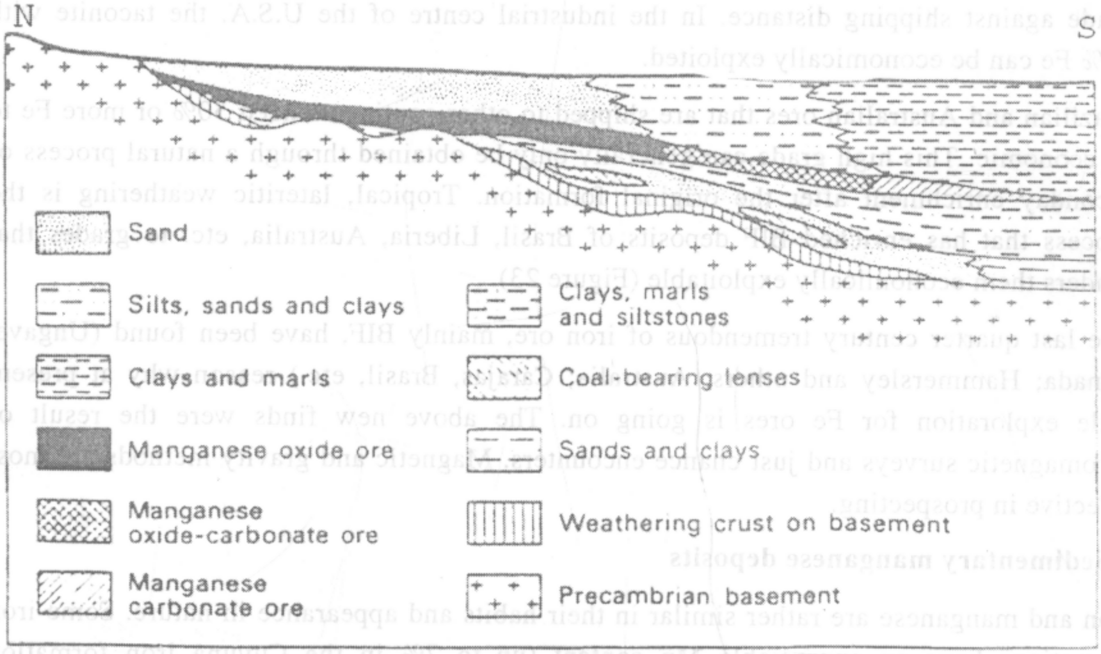



**Figure 24.** Diagrammatic cross section throught the Nikopol manganese deposits (after Varentsov, 1964).

## VOCABULARY

| | |
|---|---|
| Mineral deposits hosted by carbonates | Các mỏ khoáng trong trầm tích cacbonat |
| Subsiding basins | Các bồn sụt lún |
| Voids | Các lỗ hổng, hang hốc trong đá |
| Lagoonal carbonate environment | Môi trường cacbonat vùng vịnh |
| To adjoin | Kề bên, tiếp giáp |
| Detritial sediments are formend | Các trầm tích vụn được thành tạo |
| Abrupt (adj) | Đứt quãng, không liên tục |
| Must be born in mind | Ắt hẳn sinh ra ý nghĩ |
| Frequently carbonaceous | Thường chứa than |
| Stratabound | Mỏ giả tầng hậu sinh |
| Stratiform | Mỏ dạng tầng đồng sinh |

# CHAPTER FIVE:

# METAMORPHOGENETIC MINERAL DEPOSITS

## V.8. DEPOSITS RELATED TO REGIONAL METAMORPHISM

The word metamorphism can be defined both narrowly and broadly. In its narrow traditional sense, the word connotes the mineralogical and structural adjustment of rocks, minerals, and their textural arrays to temperatures and pressures higher than those under which they formed, commonly in environments including shear stress. The regimes most widely suggested by the term metamorphism are those of igneous, or contact, metamorphirsm and regional, or dynamothermal metamorphism. In previosu chapter we have already considered skarn and related systems at intrusive contacts of ignerous rocks with cooler wall rocks. They are an important subset of ore deposits, and are certainly related to metamorphism, but we need not consider them of many industrial minerals or rocks such as graphite, garnet, emery, kyanite-sillimanite, pyrophyllite, wollastonite, asbestos, talc, mica, and gems-varieties of corundum (ruby, sapphire), emerald, and garnet. A recently defined type of uranim deposit associated with district-scale migmatitic metamorphism includes Rossing, Soouth-West Africa, Baie Johan Beestz, Quebec, Canada, and others. So it is worthwhile to consider the role of broadscale regional metamorphism, and it is here that the broader definition comes into play. Most metamorphic petrologists would perceive of regional metamorphism as involving a series of isograds, the so-called Bar-rovian zones, extending over tens of kilometers from fresh lithified sedimentary, volcanic, or even igneous rocks thorough several increasing pressure-temperature regimens, including chlorite (greenschist), biotite, amphibole, and garnet-pyroxene (granulite) isograds. These zones are shown along with best estimates of temperature, pressure, and depth in figures of metamorphic petrology.The economic geologist must then consider how these environments and processes interact with ore deposition. Several pertinent questions come to mind:

1. What effect might increasing metamorphic rank have on pre-existing sulfide, oxide, or carbonate deposits and on their alteration assemblages? (Figures 25, 26).
2. Can we distinguish between metamorphosed, pre-existing ore deposits in, for example, a garnet-granulite host and an ore deposit that might have been formed by that metamorphism?
3. Do metamorphic processes serve to concentrate sulfides, oxides, and other minerals into economic concentrations, and how would those deposits apper?
4. What kinds of ore deposits are created by metamorphism?

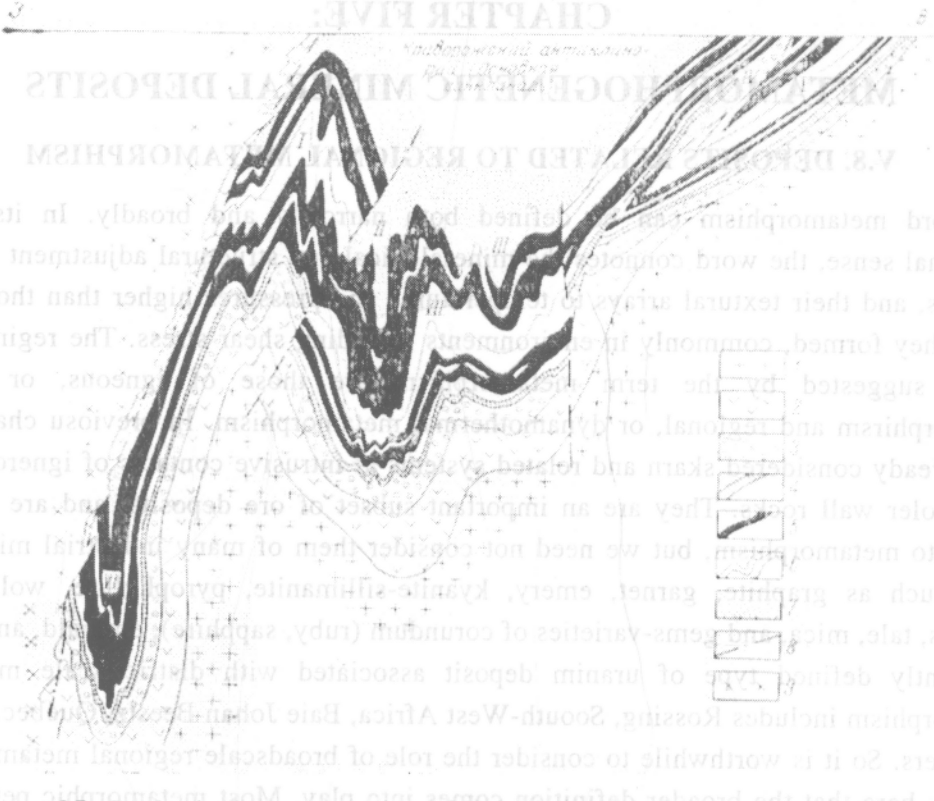


**Figure 25.** Geological cross- section of Krivoirog deposit (after I.A. Belevtsev)
1- Plagiogranite; 2- Amfibolite; 3- Krivoirog member; 4- Talc- carbonate horizone; 5- Iron layers; 6- lamenllar horizone; 7- Upper member; 8- Fault; 9- Microcline- Plagiogranite.

Answers to these question are somewhat blurred when we consider the broader definition of metamorphism recently developed by some economic geologists, a definition that includes a smetamorphism even very low-temperature phenomena like the dewatering-dehydration of a prism of sediments in a geosyncline, for example. These last environments are discussed, so in this chapter we use the traditional definition and do not include normal late stage rock-forming environments and events as "metamorphism". The student should realize that if metamorphism is defined to include any prograde, progressive heating compressing-deformimg event, then metamorphic hydrothermalism has to be included in the low-temperature end of that process.

The three subgroups of deposit can be distinguished:

a) Metamorphosed deposits: deposits formed prior to metamorphism and without significant metamorphic changes (Figures 25, 26);

b) Mixed metamorphosed- metamorphogenic deposit: deposits marginal to sub-economic, formed prior to metamorphism which have become upgrade and economic due to metamorphism;

c) Metamorphogenic deposit: deposits formed by metamorphic processes, generally involving metamorphic mineralizing fluids and structural/or tectonic traps.

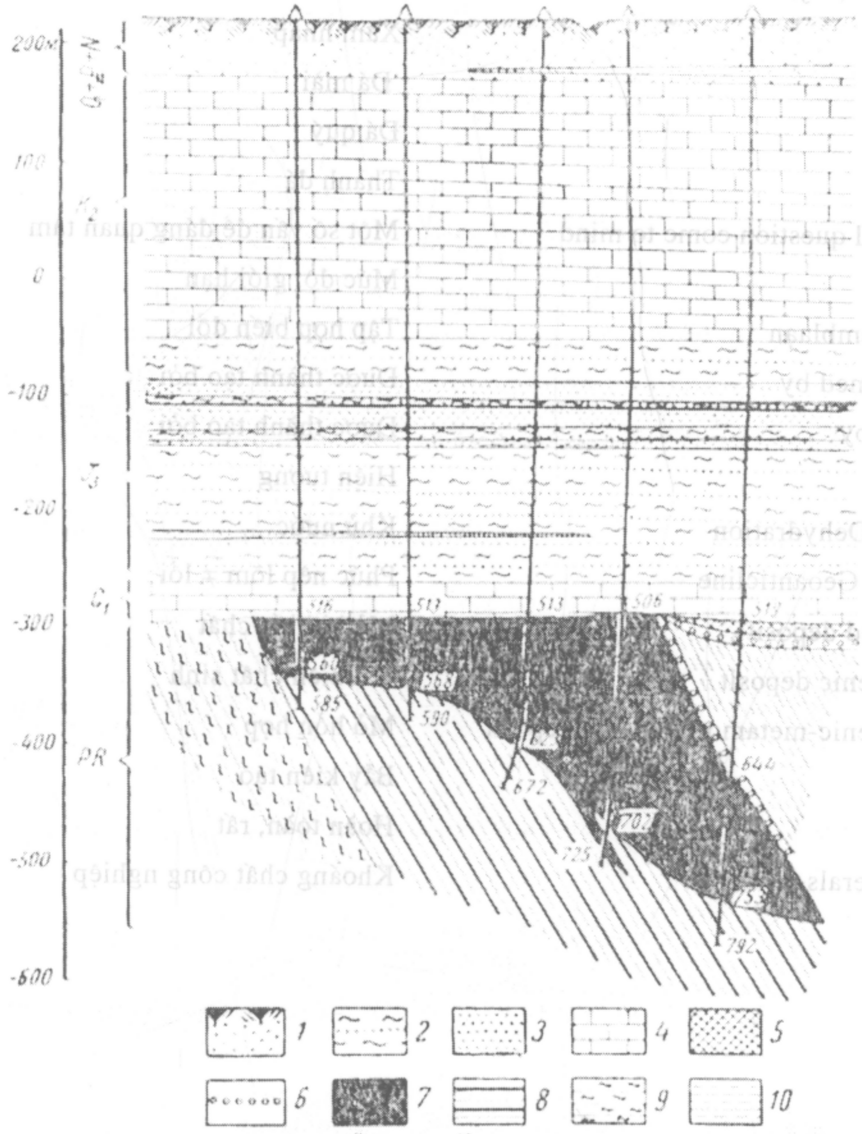



**Figure 26.** Geological cross- section of Krivoirog iron deposit (after I. A. Belevtsev).

## VOCABULARY

| | |
|---|---|
| Regional metamorphism | Biến chất khu vực |
| To connote | Bao hàm, có nghĩa là |
| Shear stress | Ứng suất cắt |
| Dynamothermal(adj) | Nhiệt động |
| Intrusive(adj) | Xâm nhập |
| Emery | Đá mài |
| Gems | Đá quý |
| Lithified | Thành đá |
| Several pertinal question come to mind | Một số vấn đề đáng quan tâm |
| Rank | Mức độ, giới hạn |
| Alteration assemblaạn | Tập hợp biến đổi |
| Have been formed by | Được thành tạo bởi |
| To be created by | Được thành tạo bởi |
| Phenomena | Hiện tượng |
| Dewatering = Dehydration | Khử nước |
| Geosyncline ≠ Geoanticline | Phức nếp lõm ≠ lồi |
| Metamorphosed deposit | Mỏ bị biến chất |
| Metamorphogenic deposit | Mỏ biến chất sinh |
| Metamorphogenic-metamorphogenic deposit | Mỏ hỗn hợp |
| Tectonic trap | Bẫy kiến tạo |
| Thorough | Hoàn toàn, rất |
| Industrial minerals & rocks | Khoáng chất công nghiệp |

# CHAPTER SIX: MINERAL EXPLORATION

## VI.1. EXPLORATION FOR SKARN DEPOSITS

Skarn deposits are characteristically of limited size and have irregular shapes and erroneous grade distributions. As such they are not too attractive as exploration targets. A number of larger skarn deposits are listed in the attached data sheet. Smaller skarn deposits ca be locally very rich and often of economic interest for small - scale mining.

Exploration mostly requires detailed fieldwork, geochemical stream sediment and soil surveys (after pilot studies have been made) and selected geophysical methods (notably magnetometry since many skarn bodies contain magnetite and/or pyrrhotite). Exploration should be guided by the contents of igneous rocks of the right composition (differentiated acid to intermediate magmas), the nature of the country rock (a carbonate rock) and the presence of a fracture or other feature that allows fluids to move (the, open system).

The irregular shape and erroneous grade distribution make skarns hard to evaluate. As a consequence, considerable drilling is needed before underground exploration is warranted. For example los santos, an over 2Mt tungsten skarn, required 14 000 m of drilling on a 30 -meter grid in order to establish the mining reserve ror the feasibility study

### VOCABULARY

| | |
|---|---|
| Limited size | Kích thước nhỏ |
| Irregular shape | Hình dạng bất kỳ |
| Erroneous grade distribution | Hàm lượng phân bố không |
| Detail fieldwork | Công tác thực địa chi tiết |
| Geochemical stream sediment | Phương pháp địa hóa bùn đáy |
| Soil survey | Địa hóa thổ nhưỡng |
| Magnetometry | Phương pháp ĐVL từ |
| Differentiated (adj) | Phân dị |
| Underground exploration | Thăm dò dưới sâu/ngầm |
| Erroneous grade distribution | Phân bố hàm lượng không đều |
| Pilot study | Nghiên cứu định hướng |

## VI.2. EXPLORATION FOR PLACER DEPOSITS

Exploration for placer deposits must first establish if all four basic requirements can be fulfilled in the area selected .The saprolite profile on sloping surfaces provides insight into a simple exploration method.The weathering profile on slightly sloping surfaces is not stable but mass movement transports the upper horizons downslope (solifluxion or creep), ultimately dumping all material into the drainage channel. The horizions from the unstructured saprolite upwards slide over the structured saprolite as substratum. All weathering resistant material, e.g. vein quartz and larger weathering resistant mineral gains, etc. become concentrated in a "stone-layer" which covers the underlying structured saprolite as a blanket (hence the term "carpedolith" suggested as an alternative for stone-layer). Sampling the stone-layer (pits, auger drill holes) may give relatively quick and cheap information about the presence of the wanted weathering-resistant minerals upslope from the sampling point. Note in the figure that, depending on the slope of the individual quartz veins, some veins describe a flat loop in the moving horizon, starting upslope through collapse before moving downslope.

Successful placer exploration generally requires as good insight in the geomorphological development - paleodrainage system, paleoclimate - of the exploration area. Surface accumulation of heavy minerals can be detected by airborne pray or ground scintillometer surveys and, more directly, by heavy mineral exploration (panning) surveys; stream sediment geochemistry generally constitutes a less appropriate tool.

In many cases the mineralized gravel is situated directly on top of the bed rock and covered by finer grained sediments (sand, peat, clay). Testing of the mineralized grevel requires Banka drilling or, if possible, pitting.

### VOCABULARY

| | |
|---|---|
| Exploration | Thăm dò |
| Sloping surface | Bề mặt dốc, nghiêng |
| Dumping | Đổ ra |
| Substratum | Phụ lớp, phụ tầng |
| Blanket | Lớp phủ |
| Sampling | Lấy mẫu |
| To sample (v) | Lấy mẫu |
| Pit | Giếng thăm dò |
| Auger drill holes | Lỗ khoan (hố khoan) thăm dò |
| Upslope | Phía ngược sườn, phí trên sườn |

| | |
|---|---|
| Depending on | Tuỳ thuộc, phụ thuộc |
| Individual quartz veins | Các mạch thạch anh đơn lẻ |
| Flat loop | Mạch vòng (hay mét) phẳng |
| Good insight | Sự hiểu biết sâu sắc, tinh thông |
| Geomorphologic development | Sự phát triển địa mạo |
| Paleo- | Cổ, xưa |
| Paleoclimate | Cổ khí hậu |
| Paleodrainage system | Hệ thống sông suối cổ |
| Airborne γ-ray | Phương pháp đo γ hàng không |
| Ground scintillometer survey | Phương pháp đo vẽ quang phổ kế nhìn trực tiếp trên mặt đất |
| Heavy mineral exploration survey | Phương pháp thăm dò trọng sa (tìm kiếm trọng sa) |
| Stream sediment geochemistry | Phương pháp địa hóa trầm tích bùn đáy |
| Mineralised gravel | Cuội sỏi chứa quặng |
| Downslope | Dưới sườn; theo sườn |
| Solifluxion | Trượt đất, đất chảy |

# PART THREE: DESCRIPTION OF DEPOSITS

## CHAPTER VII

### VII.1. Pb-Zn-Ag ORE DEPOSIT OF THE PINNACLES

### I. INTRODUCTION

The Pinnacles mine, at lat. 141°20' E, long. 32°3' S, is 10 miles south - west of Broken Hill and, with a production and ore expectancy of about 200,000 tons, is the largest known sulphide deposit of the district outside of the Broken Hill lode. Since the last comprehensive paper in the Pinnacles (King, 1953) further detailed mapping of the Pinnacles Mine and the general area has led to a reinterpretation of the geology. The results of this additional study coupled with those from further work in the Broken Hill area stress the strong resemblance between these two deposits. The similarity of the lode systems and the general environment of the ore deposits argue a common genesis for both orebodies. In addition, a closer definition of the stratigraphy of the Pinnacles ore environment has established that horrizons such as the aplitic gneiss are not unique in the'succession as formerly thought but are repeated at several stratigraphic levels. This observation allows a simpler interpretation of the structure as it eliminates the need for postulating tight isoclinal folding.

### II. STRATIGRAPHIC SUCCESSION

The generalized stratigraphic succession of the Pinnacles area comprises sillimanite, biotite and garnet gneisses separating the six numbered formations.

Underlying this succession in the Stirling Vale erea, north of the Pinacles, is a similar sequence of rocks of identical lithological character. This lower sequence, which does not include quartz magnetite, is represented in part in the north-east corner of Fig.In the regional interpretation of the stratigraphy of the Broken Hill mine area.

Repetition of the principal marker horizons in the sedimentary environment is common and occurs in a cyclic manner as shown by Formation 5, the depositional cycle containing the lode horizons of the Pinnacles mine.

The thickness of individual beds can be extremely variable and sedimentary lensing is common, particularly within the lode horizons and the iron-rich beds. The lenticular outcrops of quartz magnetite forming the three Pinnacles strikingly illustrate this feature. The rapid thinning of the group of beds enclosing the Pinnacles lode horizon, northwards towards the Middle Pinnacle and beyond, shows that such sedimentary lensing also occurs on a large scale.

## III. STRUCTURE

The major structural element is the broad, open, N-S trending syncline.The fold has a predominantly flat undulating pitch to the south but north pitching drag folds exposed south of the South Pinnacle suggest a reversal of pitch of the main syncline east of the South Pinacle. The consequent closure of the structure due to this pitch reversal is thought to limit the southward expression of the major part of the Pinacles sequence in this area.

While the west limb of the syncline dips uniformy east at a moderate angle the east limb steepens from a moderate to steep westerly dip in the north to a vertical and possibly overturned steep easterly dip in the south.

Major shears with the two principal trends of WNW- ESE and NW - SE, and now represented by wide zones of sericite schist, cut across and modify the basic outline of the major fold. The system trending WNW - ESE is more strongly developed in the southern part of the area and parallels the major Thackaringa - Pinnacles fault zone located about one mile south of the Pinacles mine.

Strong buckling of the beds, increasing in intensity towards the south, occurs in close association with the sericite zones and is attributed to drag folding of the beds by the shearing. These folds pich in a general ESE to SE direction at a flat to moderate angle.

In the Pinnacles mine area where the pattern of drag folding is most pronouced and is clearly outlined by the orebody, the axes of the folds trend parallel to a converging set of sericite zones or shears. These relationships, together with the attitude and position of the ore lenses, suggest that shearing is responsible for the buckling of the lode and enclosing rocks. The strong attentuation of the lode horizons and their frequent representation as disconected lenses of ore in the plane of the shears support this view. In the southern part of the mine area the ore beds terminate on a wide shear zone along which the ore thins out and disappears.

## IV. MINERALIZATION

The Pinnacles mine has produced ore with a typical metal content of 11 per cent lead, 17 oz/ton silver and 2.5 per cent zinc chiefly from one lode, the Lead Lode. Production and ore expectancy indicate a total of about 200,000 tons to a depth of 250 ft.

Conformably above and also below the Lead Lode is at least one, and possibly two Zinc Lodes. The principal lodes, of much the same thickness as the Lead Lode (5ft), are located approximately 10 ft stratigraphically above and below that horizon. The Zinc Lodes are less persistent and more patchy and have metal rations more variable than the Lead Lode.

In addition to the lodes of the Pinnacles ore horizon, lode material, represented by quartz - gahnite mineralization, is found in gneisses in association with garnet hematite magnetite and amphibolite horizons. These minor lode occurrences occur stratigraphically above and below the Pinnacles ore horizon and have failed to produce significant orebodies.

## V. NATURE OF THE ENVIRONMENT

A comparison of the Pinnacles and Broken Hill area reveals that they are characterized by the same kind of marker horizons which, although not identical in type, have sufficiently close lithological resemblance to indicate that they were deposited under closely similar conditions of sedimentation.

The occurrence of conformable Zinc Lode horizons both above and below the Lead Lode horizon at the Pinnacles shows that this orebody, like that of Broken Hill, is a composite deposit which displays a cyclic pattern in the ore layers. Furthermore this cyclical pattern is a reflection of the larger pattern displayed by the marker horizons of the ore environment and serves to show that the ore is intimately related to, and forms an integral part of, a particular and distinctive sedimentary environment

## VOCABULARY

| | |
|---|---|
| Ore expectancy of | Triển vọng quặng |
| Aplitic gneiss | Gơnai aplit |
| Stratigraphic succession | Thứ tự địa tầng |
| Postulating | Tiền đề; đặt cơ sở |
| Repetition | Sự lặp lại |
| Marker horizon | Tầng đánh dấu |
| Lode | Mạch quặng/mạch |
| Isoclinal folding | Thành tạo nếp uốn đơn nghiêng |
| Flat undulating pitch | Thế nằm lượn sóng thoải |
| Lim of syncline/ anticline | Cánh nếp lõm/nếp lồi |
| Shears | Dịch chuyển, đứt gãy |
| Comformable | Chỉnh hợp |
| Strong bucling of the beds | Các lớp bị uốn cong mạnh |
| To be pronounced | Rõ ràng, rõ rệt |
| Frequent representation | Biểu hiện thường gặp |
| Dissconnected lenses | Các thấu kính không liên tục |
| The ore lods terminate on a wide shear zone | Các mạch quặng tập trung trong một đới xiết ép rộng |

| | |
|---|---|
| To resemble to | Giống với |
| Eliminate (v) | Loại bỏ; khử |
| Postulate (v) | Lượn sóng |
| Lenticular outcrop | Vết lộ dạng thấu kính |

## VII.2. GOLD DEPOSIT OF HILL 50 MINE

### I. INTRODUCTION

The hill 50 mine is in the Murchison Goldfield, at Boogardie three miles west of the town of Mount Magnet and some 300 miles north-west of Kalgoorlie.

Since 1951 when the 600 ft level was being developed (Finucane, 1953) the depth of the mine has increased rapidly to the 2,760 ft level. Development and mining over this range of depth has disclosed a number of new geological and structural features.

Since the inception of operatinons in 1936 the Hill 50 Gold Mine N.L. company has produced 2,121,079 long tons of ore for a recovery of 1,058,054 fine oz of gold from the orebody up to 30th June 1964. This represents a recovery grade of 9.98 dwt/ton gold. At 30th June 1964 the ore reserve stood at 587,300 tons at 6.5 dwt/ton, from which approximately 175,000 tons are currently being produced per annual.

### II. GEOLOGY

The Mount Magnet District of the Murchison Gold-field is situated in a slightly elongated north-south trending greenstone belt, some twenty miles in length and surrounded on all sides by granite.

The rock belt is typical of the Kalgoorlie Series as developed elsewhere in the state of Western Australia.

The mine has recently been fact mapped over a few miles in length (Hare and Jones, 1960), checked and reinterpreted by the author. This work has shown that the area is completely folded and faulted, the overall bedding trend being approximately 3300 and dipping steeply north-east at an average of some 750. The folding is asymmetric and surrounding the mine area the rocks appear to form the overturned eastern limb of a syncline, which immediately north of the mine plunges at 600 to 700 south. Smaller folds plunge both north and south at widely varying angles, some almost certainly being overturned.

Numerous faults of varying strength displacement may be observed in the mine area. Most of these of these strike at approximately 300, dip near vertically and display north block east movement. A second set of faults, only occasionally developed, strike at 70 to 800, dip vertically and have north block west movement. These two fault types are clearly complimentary to each other and, with the folding, could result from one original stress, a compression applied near horizontally and at right angles to the present strike trend of the rocks.

A third type of fault has developed, apparently during the advanced stage of folding. In the mapped area in the vicinity of the mine two major and a few minor faults of this nature may be observed. At a certain stage of development of a drag fold shearing develops on the middle limp of the fold and further deformation results in a fault along this limb, so increasing the offset between the anticlinal and synclinal portions of the drag. In strike these faults are approximately parallel to the 300 typrs described above but are opposite in offset in the mine area because the drag fold shape is here left hand i.e. north block west. Their dip is variable and dependant on the plunge of the originating fold.

Rocks in the mine area consist of two types of greenstone, banded iron formation (BIF) and feldspar porphyry. The greenstone varieties are fine to medium-grained, basic in composition and medium to coarse-grained, ultrabasic in composition.They are undoubtedly metamorphosed lavas.

Some twenty BIF or jaspilite horizons occur in the 4000 to 5000 ft width of the rock succession mapped in the mine area. They are conformable and mostly range from a few to 20 ft in width. A few exceed this width whilst the main member, the host of the hill 50 0rebody, reaches 100 to 140 ft, width at its maximum development.

Numerous feldspar porphyry dykes and less abundant sills occur throughout the area. This intrusion post-dated at least some and probably most of the deformation as instanced by porphyries filling many of the fault positions.

Although Hill 50 is the only major orebody known to date in the Mount Magnet District very numerous minor shoots of gold mineralization occur throughout. Within a radius of a few miles along strike from the Hill 50 orebody this mineralization is almost entirely confined to the filling of fault planes where have BIF margins.

Mineralization was clearly very selective to these two features and cannot be observed extending along faults for more than a few feet where walls are entirely green-stone or porphyry. The mineralization consists of pyrrhotite, pyrite, quartz and gold, the latter only occasionally coarse enough to be visible to the eye.

## III. GEOLOGY AND STRUCTURE OF THE OREBODY

The Hill 50 orebody occurs within the widest BIF horizon known in the area- the Hill 50 BIF. Its width varies from 60 to 140 ft in the immediate mine area. The ore itself may be mineralized BIF with variable amounts of quartz or in the higher grade gold sections a siliceous, pyrrhotitic, pyritic lode with little or no remnants of BIF. In these latter zones sulphide content may be 50 to 80 per cent of the total rock.

The orebody is an outstanding example of ore localization resulting from the combination of a number of structural conditions developing at the one focal point.

In this case four key structural features have developed during deformation and so located the Hill 50 orebody. Had only two three of these conditions developed, observations suggest that only minor oreshoots similar to those nearby wuld have developed.

The accompanying level plans and longitudinal section show these structures. The major controlling feature is that of a north block west fault apparent-ly originating, as described earlier, from a series of small or one large left hand drag fold. The BIF displays folding on approaching this fault and at the fault itself the bed is gently folded into and sheared along the fracture zone. This is unlike the behaviour of the B.I.F.'s where cut by faults of simple compressive origin. The beds are here snapped sharply and show only miror bending or fault drag at the point of intersection. When the bottom level of the mine was 613 ft it was felt (Finucane, 1953) that the controlling structural feature was a 600 north plunging anticline. Deeper development however has disclosed that this feature was a subsidiary fold to the zone responsible for the major fault. The plan displacement in the BIF resulting from this fault is approximately 900 ft.

The plunge of the intersection of the ore-bearing Hill 50 BIF and the fault averages 650 to the north from surface to the 2470 ft horizon. From here to the 2,760 ft level the plunge is near vertical and it appears to be turning over to a south plunge at depth, in accordance with the southerly plunging syncline north of the mine.

The overall ore development trends with the plunge of the major fault, but in detail the orebody is made up of a number of vertical or near vertical plunging shoots. These are positioned by a series of steep deeping faults with horizonal dislacements less than 50 ft. These faults are the 300 strike variety, mostly north block east movement (simple compression) with two of the north block east movement (simple compression) with two of the north block west type (fold margin). Some of these faults are occupied by feldspar porphyries, the third controlling feature, and the higher grade, wider ore-shoots definitely favour these locationns. The oreshoot immediately south of the main shaft is the highest grade and widest so far mined. A fault with porphyry-BIF walls is apparenth a more effective channelway for mineralization than one or both walls of BIF.

Finally there is a fourth factor affecting ore devel-opment, that of the width of the Hill 50 BIF, and there are two reasons for this influence. As ore occurs specific-ally in BIF both at the intersection of and along the bed near a fault, it follows that the wider the BIF the larger and more significant the ore developmen. Secondly the BIF has clearly behaved more competently to stress than the surrounding greenstones and fractures with minor displacement tend to be well defined in the greenstone. The wider the BIF the better defined and more significant the fracture.

Considerable variation in grade and tons per vertical foot existed in the orebody between surface and the 2,760 ft level. Above 600 ft and below 1,400 ft depths the orebody varied between 500 and 1,000 tons per vertical foot at 5 to 8 dwt/ton gold. Between these two depths ore develoment varied from 1,000 to 1,700 tons per vertical foot at 10 to 25 dwt/ton gold, e.g. at the 1,060 ft level developed ore totalled 1,526 tons per vertical foot at 21.1 dwt/ton gold, and stoping reached 120 ft width in this genral zone.

The maximum development of the Hill 50 orebody clearly lies between 600 and 1,400 ft depths and this coincides with zone in wich the four structural features described are in the closest association.

It is of interest to note that the Hill 50 company are currently pursuing an active exploration programme. With ore extengding beneath the 2,760 ft level it is intended to test the continuation of this and porphyry system in depth. This system may again axist in close proximity to the major fault provided the latter continues on the anticipated southerly plunge.

## VOCABULARY

| | |
|---|---|
| Gold deposits of hill 50 mines | Đồi 50 mỏ vàng |
| Development & mining | Triển khai và khai thác |
| Inception (n) | Sự bắt đầu, khởi đầu |
| Orebody | Thân quặng |
| Greenstore belt | Đai đá màu lục |
| Granite | Granit |
| Has been fact mapped | Đã lập bản đồ thực tế |
| To be folded & faulted | Bị uốn nếp & đứt gẫy |
| Overall bedding trend | Phương chung của lớp |
| To be dipping steeply north-east at an average of some $75^0$ | Cắm dốc về phía đông-bắc, trung bình $75^0$ |
| Mine area | Diện tích khu mỏ |
| Limb of a syncline | Cánh nếp lõm |
| To plunge | Chìm, chúc, cắm |
| Strength & displacement | Cường độ và biên độ dịch chuyển |
| To strike (v) | Phương, hướng (về) |

| | |
|---|---|
| Present strike trend of the rocks | Đường phương hiện tại của các đá |
| In the mapped area | Trong diện tích đã đo vẽ bản đồ |
| Drag fold shearing | Sự dịch chuyển lớp uốn kéo theo |
| Offset | Sự phân nhánh, sự phân chia |
| Anticlinal (adj) | Nếp lồi |
| Banded iron formation (BIF) | Thành tạo sắt phân lớp |
| Feldspar porphyry | Pocfia fenpat |
| Basic incomposition | Thành phần bazơ |
| Ultrabasic ~ | Thành phần siêu bazơ |
| Jaspilite horizons | Các tầng jaspilit |
| To be conformable | Chỉnh hợp, khớp đều |
| Filling of fault planes | Lấp đầy mặt đứt gẫy |
| Mineralization | Sự khoáng hóa, khoáng hóa |
| Pyrrhotite | Pyrotin |
| Pyrite | Pyrit |
| Quartz | Thạch anh |
| Gold | Vàng |
| Siliceous | (Thuộc) silic |
| To be visible to the eye | Có thể nhìn thấy bằng mắt thường |
| Sulphide content | Hàm lượng sunfua |
| Ore localization | Sự tập trung quặng, sự cư trú của quặng |
| Key structural features | Các đặc điểm cấu trúc chính |
| Oreshoot | Bướu quặng |
| Accompanying level plans | Các bình đồ độ cao kèm theo |
| Longitudinal section | Mặt cắt dọc |
| Controlling feature | Đặc điểm khống chế |
| To be apparently originating | Dường như phát sinh đầu tiên, được hình thành dường như đầu tiên |
| To be gently folded & | Bị uốn nếp thoải và dịch |
| Sheared along the fracture zone | chuyển dọc theo đới dập vỡ |
| Compressive origin | Có nguồn gốc nén ép |
| To be snapped | Bị gãy, đứt |
| Point of intersection | Điểm giao nhau, nơi giao nhau |

## VII.3. CASSITERITE DEPOSITS OF SOUTHERN QUEENSLAND

## I. INTRODUCTION

The Stanthorpe Mineral Field has been the major Queensland source of tin ore concentrates south of Townsville. Small production has come from Rocky Creek, $35\frac{1}{2}$ miles south-west of Gayndah, and 150 miles north-west of Brisbane (Ball,1912; Morton,1924), and from the headwaters of Crow's Nest Creek, 2 to 3 miles east of Crow's nest, and 60 miles west of brisbane (Ball, 1903). Stanniferous alluvium along streams in these two areas has been derived from cassiterite - bearing greisen and quartz veins in the granites of intrusive complexes of Permian to Triassic age.

### 1. Location and history

The stanniferous portion of the Stanthorpe Mineral Field comprises an area of about 300 sq. miles, centred roughly on the town of Stantorpe (lat. 28$^0$39' S, long. 151$^0$56' E) some 140 miles by road south - west of Brisbane. This area lies south of the Herries Range and is bounded on the east and south by the State border.

Alluvial cassiterite was discovered in 1854, but not worked until 1872. The deposits worked in the early years were extremely rich but the primitive methods of concentration resulted in poor recoveries. Despite this the first ten years yielded two - thirds of the total production to date. A gradual decline in output followed until the commencement of dredging operations in 1901 when production rose appreciably. Following this brief revival the output once again declined and in recent years was less than 20 tons annually. A renewal of activity in 1962 resulted in a production of 70 tons of concentrate.

To the end of 1962, the Stanthorpe Mineral Field produced 47,146 tons of tin ore concentrates valued at ε3,164,755 being more than one-quarter of Queensland's total tin output.

### 2. General geology

The area is a denuded tableland averaging about 2,500 ft above sea level, with ridges and broken hills rising to over 4,00 ft. Shallow meandering streams flow down the broad valleys between the ridges.

A complex granitic mass of Permian to Triassic age, the northern extension of the New England Batholith, crops out over the major portion of the tinfield. Igneous activity in the area seem to have commenced with the emplacement of grey feldspar porphyry. This has been intruded in the southern portion of the tinfield by all granitic phases of the batholit which come in contact with it. The complex consists of a series of intrusions, commencing with hornblende-augite-biotite microgranite (Blue Granite), and passing with increasing acidity through biotite granite (Maryland Granite), porphyritic sphene granite, coarse acid granite (Stanthorpe Granite), fine-grained leucocratic granite (Sandy Granite) to aplites. The coarse-grained pink to grey Stanthorpe Granite has the largest area of outcrop. The Sandy Granite, which intrudes the Stanthorpe Granite, is a fine-grained pinkish grey rock typically developed to the east and north of Stanthorpe.

In the extreme western portion of the tinfield the batholith granites intrude marine sediments and pyro-clastics of probable Lower Permian age. These consist of slate, shale, mudstone, silttone, sandstone, conglomerate, chert, minor unfossiliferous limestone, tuffs and volcanic breccia. The strike of the sediments varies from NW to N with generally steep to vertical dips. Lucas (1960) found that the Palaeozoic sediments in the Texas-Pikedale area 20 miles west of Stanthorpe had been affected by a strong epi-Middle Permian orogeny. However this compression appears to have had little effect on the sediments on the eastern side of the granite massif in the Silverwood area 21 miles north of Stanthorpe where Bryan (1926) considered that the Permian was subjected to gentle epeirogenic uplift with resultant tension and block faulting.

The Taxas erea 50 miles south- west of Stanthorpe has been stabilized since the Upper Permian, and the epi-Permian batholith, which in the Silverwood area was thought by Bryan (1926) to have welled up into a region of tension shortly after the resulting block faulting, is post - tectonic.

Lucas (1960) considered that the area now occupied by the igneous complex was probably the site of a "high" from Middle Devonian to Upper Permian times as the stratigraphic and structural histories are markedly different on the eastern and western sides of the batholith. The metamorphic effects produced by the intrusion are generally of low intensity. Along the margin of the contact with the granite tin, coper, gold, silver, lead and zinc mineralization occurs in the sediments.

The two main joint systems in the granites vary in direction from NE to ENE, and from NW to NNW. Along these joints, especially in the Sandy Granite, veins of quartz and greisen carrying cassiterite, wolframite and molybdenite were emplaced. The rich concentrations of alluvial cassiterite have been derived from widespread finely disseminated cassiterite and innumerable stanni-ferous quartz and greisen veins is a series of porphyritic acid dykes which are regarded as the final pase of the intrusion. Quartz porphyry dykes in the Snady Granite frequently contain disseminated cassiterite. Similar veins and dykes within the Stanthorpe granite are only occasionally stanniferous. Diorite, mica lamprophyre, basalt and dolerite dykes are believed to belong to a later period of igneous activity.

## 3. Economic geology

### *a. Alluvial deposits*

Alluvial cassiterite has been won from practically the whole of the area drained by the Severn River and its main tributaries, Spring Creek, the Broadwater, Quart Pot, Kettle Swamp and Four Mile Creeks. The Main alluvial deposits are restricted to alluvium of Recent age forming flats along present stream channels. The beds of these streams were also extensived worked. The alluvium is mainly of granite-derived sand containing sub - angular to well rounded pebbles of quartz and occasional boulders of granite; the sand grains are often strongly cemented by clay and iron oxides. Patches of stanniferous wash are preserved at the base of this layer. The average depth of allumvium is approximately 6 ft and ranges from a few inches to a maximum of 20 ft.

Mottled stanniferous gravels, sand and clay of probable Pleistocene age occur on the top of ridges well above the present streams. They are too low grade to constitute an important source of cassiterite but erosion of them has contributed significant amounts of cassiterite to the Recent alluvium.

The grain size of the cassiterite varies from very fine sand-sized particles to coarsely crystalline slugs more than an inch in diameter. Although some of the cassiterite is well rounded a high percentage in angular and exhibits well developed crystal faces. The richest stream tin deposits occurred in areas enriched by eluvial cassiterite.

The cassiterite is dominantly black but notable proportions of white, yellow, amber, and ruby coloured varieties are present. The mineral is very pure, assaying in excess of 75 per cent metallic tin.

Widespread topaz, together with monazite, wolframite, and lesser amounts of zircon, sapphire, tourmaline and beryl, and occasional flakes of gold, are associated with the cassiterite in the alluvium. A few small diamonds have also been found. Ilmenite frequently occurs in stanniferous deposits along streams draining the Stanthorpe granite.

### *b. Lode deposits*

Workable lodes of cassiterite are restricted to the south - western part of the area, between the Severn River and the State border. The main lode deposits worked were in the Kilminster, Red Rock and Sundown Districts. With the exception of the Sundown area the deposits are confined to the contact zones of small bosses of Sandy granite.

The formation of the lodes, both in the granite and in the intruded sediments, has been controlled by vertical or near vertical north - easterly and north-westerly trending joints. Along these joints cassiterite occurs in quartz, aplite and greisen veins as fine disseminations, coarsely crystalline bunches and lens- shaped oreshoots. Some oreshoots have been formed by replacement of the adjacemt country rock. In the majority of the lodes the distribution of cassiterite is very patches, and the ore pinches rapidly both lateralky vertically. At the Comet and Sundown Mines some ore lenses in north-east vertical joints in slates terminate at a system of inclined cross joints.

Arsenopyrite is often associated with cassiterite in many of the lodes especially in the Red Rock - Sundown area, where in some of the oreshoots the primary ore consists dominantly of arsenopyrite with varying proportions of associated cassiterite, chalcopyrite, wolframite, molybdenite, pyrite, sphalerite and galena. Quartz brecciated chloritic country rock, calcite, fluorite, siderite and tourmaline commonly constitute the gangue.

Although most of the deposits were only worked to shallow depths, at the Sundown mine a lode 270 ft long, consisting of a series of rich lenses, was exploited to a depth of 251 ft. The average cassiterite content of ore from this mine appears to have been approximately 5 per cent though in places it carried as high as 11 per cent. The Sundown mine, the major producer of lode cassiterite on the Stanthorpe Field, has yielded approximately 287 tons of tin ore concentrates inclusive of a small tonnage from an adjacent copper lode.

## VOCABULARY

| | |
|---|---|
| Cassiterite deposits | Các mỏ casiterit |
| Source of tin ore concentrates | Nguồn cung cấp tinh quặng thiếc |
| Headwater | Thượng nguồn |
| Stanniferous alluvium | Aluvi chứa stanin |
| Primitive methods of concentration | Các phương pháp làm giàu đơn giản |
| Dredginy operation | Khai thác bằng tàu cuốc/nạo vét |
| Denuded tableland | Cao nguyên bị bóc mòn |
| Tinfield | Trường quặng thiếc/vùng mỏ thiếc |
| Have been intruded by | Bị xâm nhập bởi |
| Commen cing with | Bắt đầu bằng |
| Fine-grained leucocratic gratine | Granit sáng màu hạt mịn |
| Pyroclactics | Đá vụn núi lửa |
| Strike | Phương vị đường phương |
| Steep to vertical dips | Góc cắm góc dốc đến thẳng đứng |
| Was subjected | Đã bị, đã phải |
| Uplift | Phay nghịch, địa lũy |
| To have been stabilized | Đã bình ổn |

| | |
|---|---|
| To well up into | Trở thành |
| Middle Devonian | Thế Devon giữa |
| Upper Permian | Thế Pecmi thượng |
| Metamorphic effects produced by | Hiệu ứng biến chất gây nên bởi |
| Along the margin of | Dọc theo ranh giới |
| Greizen carrying W, Sn | Greizen chứa W, Sn |
| Finely disseminated cassiterite | Cassiterite xâm tán mịn |
| Igneous activity | Hoạt động xâm nhập |
| Has been won | Thu được, lấy được |
| Area drained by | Vùng bị chia cắt bởi |
| Beds of these streams | Lòng suối, đáy suối |
| Tolle strongly cemented by | (Bị) gắn chặt bởi, gắn kết bởi |
| Well developed crystal faces | Phát triển các mạch tinh thể rất đẹp/rõ ràng |
| Patches | Các mảnh vụn, các đám |
| Workable lodes | Các mạch có thể khai thác được |
| To have been controlled by | Được khống chế bởi |
| Bunches, Cairngorm | Bướu quặng, ổ quặng |

## VII.4. MIDDLESEX MINERAL DISTRICT

### I. INTRODUCTION

This field is situated about 25 miles south - west of Devonprt in the central north of Tasmania. Prospecting was originally stimulated by the discovery of gold in the Forth River by James Smith in 1859. Silver-lead deposits at Round Hill were discovered in 1878, gold on the Five Mile Rise in the 1880's and near bell Mount in 1892. Numerous small lodes carrying tin and tungsten ores around the granite on Dolcoath hill were discovered between 1891 and 1893.

Few of the mines surveyed for more than a few years. The major producers were the Shepherd and Murphy Mine which has produced 550 tons of tin, 242.2 tons of $WO_3$ and 71.3 tons of metallic bismuth; and the Round Hill Mine which produced 4,690 tons of lead, 389,679 oz of silver and 1,320 oz of gold. Production records for the field are incomplete but the total production is estimated to be 8,300 oz of gold, 393,000 oz of silver, 4,927 tons of lead, 75.6 tons of bismuth, 572 tons of tin and 335 tons of wolframite.

## II. GEOLOGY

Most of the mineral deposits are in Lower palaeozoic rocks a few miles north of the boundary of the Lower Palaeozoic basin and the Precambrian nucleus lying to the south and west.The stratigraphic succession is set out in Table 1.

**Table 1.** Stratigraphic succession of Middlesex District.

| Age | Thickness (ft) | Unit |
|---|---|---|
| Tertiry | 0 - 800 | Basalt |
| | unconformity | |
| Devonian | | Dove? and Dol-coath granites |
| | unconformity | |
| Ordovician | 300 | Gordon Lime-stone |
| | 800 | Moina Sand-stone |
| | 0 - 800 | Roland Conglomerate |
| | unconformity | |
| Upper to Middle | several thousand | greywacke; quartz feldspar porphyries |
| | unconformity | |
| Precambrian | several thousand | Quartzite and metapelites |

The Ordovician rocks have been folded into a series of large scale E - WW trending folds with a superimposed set of NWW trending folds and breakthrusts. The contrast in fold styles between the concentrically folded Ordovician systems and the shear folded Cambrian rocks has resulted in decollement action along the Cambro-Ordovican unconformity. This folding is regarded as Lower to Middle Devonian in age and correlated with the Tabberabberan Orogeny.

The Dove Granite was emplaced along or close to the Lower Palaeozoic - Precambrian Boundary, whilst the petrologically distinct, tin - bearing Dolcoath Granite is intruded as a stock, 2 to 3 miles in diameter, about 5 miles north of this boundary. Near the Dolcoath Granite the Gordon Limestone has been contact metamorphosed to a garnet-pyroxene rock locally referred to as skarn.

Remnants of Tertiary basalt occupy the interfluves between th major streams and obscure much of the potential mineral - bearing country. Small deep leads containing cassiterite, wolframite and bismuthinite were worked in the upper levels of Shepherd and Murphy Mine.

## III. MINERAL DEPOSITS

Wolframite - cassiterite deposits with accessory molybdenite occur in and adjacent to the Dolcoath Granite whilst cassiterite with accessory wolframite and bismuthinite occurs further out. Bismuth - gold and silver - lead ores with gold occur with increasing distance from the contact showing a sub - zonal distribution. The southern gold and silver-lead ores may, however, be related to the Dove Granite.

### 1. Tin, tungsten bismuth deposits

The Shepherd and Murphy Mine is situated on Bismuth Creek near Moina. The most recent description of this mine is that of Blake (1956).

The orebodies are partly in indurated quartzite of the Moina Sandstone and partly in contact metamorphosed Gordon Limestone. The boundary between the two formations passes through the mine workings but has no appreciable effect on the lodes. Within the workings the sediments strike generally N - S and dip from $30^0$ to $50^0$ W. The lode system consists of six roughly parallel quartz veins averaging between 8 and 20 in, in width and up to 1,300 ft long, dipping south at about $85^0$.

These lodes have been worked to a depth of 340 ft from three adits and to a further depth of 150 ft in two levels from a shaft. The veins carry wolframite, cassiterte and bismuthinite, together with small amouts of native bismuth, sphalerite, molybdenite, chalcopyrite, pyrite, scheelite, arsenopyrite and galena. The gangue minerals are quartz with minor fluorite, topaz, beryl phlogopite, muscovite, chlorite, and laumontite. Twelvetrees (1913) reported that the lodes were enriched in bismutite in the upper levels.

Generally the ore was frozen to the walls so that some of the wall rock had to be mined with the ore. Twelve-bismuthinite extended for some distance into the walls. Reid (1919) indicated that the ratio of cassiterite: wolframite : bismuthite was about 20 : 12 : 3 whilst Williams (1957) showed that on the lower levels the ratio of cassiterite: wolframite was about 1: 4 indicating a decline in the ratio with increasing depth. Williams also reported that the garnet formed by contact metamorphism approaches grossularite in composition. He attributed the lack of significant scheelite mineralization in the skarn rock to the fact that the available calcium from the limestone was bound up in the garnet prior to mineralization.

Ore reserves at the time the mine closed were estimated by Robinson (1957) as 42.400 tons of probable ore and 44,600 tons of possible ore. East of the Shepherd and Murphy, at the All Nations Mine, two or possibly three veins are contained in indurated quartzite and shale of the Moina Sandstone. They are up to 24 in. wide, strike $290^0$ and dip west at $25^0$ to $35^0$ and have been worked over a maximum distance of about 1,500 ft. The veins are cut by a low angle thrust fault which limits the orebodies at depth and.

## VOCABULARY

| | |
|---|---|
| Amenable bauxite ores of aluminium | Quặng boxit khai thác để sản xuất nhôm |
| Amelioration | Sự cải tạo |
| Tin granites | Granit chứa thiếc |
| Soil profiles | Các mặt cắt qua đất trồng (thổ nhưỡng) |
| To alter | Biến đổi |
| Carbon dioxide | $CO_2$ |
| Appreciable amounts of humid | Một lượng có thể thấy được (có thể đánh giá được) các axit hữu cơ |
| To percolate | Lạc qua, thấm qua |
| Zone of accretion | Đới thoáng khí |
| ~ saturation | Đới bão hoà |
| May react with | Có thể tác dụng với |
| Groundwater table | Mực nước ngầm |
| Neutral ova slightly alkaline | Trung hòa hay bazơ yếu |
| Fluid phase | Pha lỏng |
| Buffer | Vùng đệm |
| The rate of mineral chemical reactions | Tỷ lệ các phản ứng hóa học của các khoáng vật |
| The depth to which weathering takes place | Độ sâu phong hóa hay độ sâu mà quá trình phong hóa đạt tới |
| Can oxidise, hydrate and carbonates rock-forming silicates | Có thể oxy hóa, hydrat hoá và cacbonat hóa các khoáng vật tạo đá silicat |
| To be deeply weathered | Bị phong hóa mạnh mẽ, sâu sắc |
| Metamorphic rocks | Các đá biến chất |
| Spessartite garnets | Khoáng vật spesactit của nhóm granat |
| Pellets | Các hạt nhỏ |
| Was originally stimulated | Bị/ được thúc đẩy |

# VII.5. GOLD DEPOSIT OF GOLDEN PLATEAU

## I. INTRODUCTION

The Golden Plateau deposit, 225 miles north-west of Brisbane at lat. 25°17' S, long. 150°17' E, is the only major producer of gold in the Cracow Goldfield, which was discovered in 1931. For many years Golden Plateau has been the only mine in Queensland, apart from Mount Morgan, to produce substantial amounts of gold. Since 1933 the deposit has been mined continuously by Golden Plateau N. L., and up to 1963 a total of 1,110, 393 tons of ore were produced for a yield of 443,206 fine oz of gold and 328, 793 fine oz of silver. For the year ended 30th June, 1963, some 33,820 tons of ore were treated for a yield of 13,678 fine oz of gold, averaging 8.1 dwt/ton, ar 14,441 fine oz of silver.

## II. GENERAL GEOLOGY

The deposit occurs in the Camboon Andesite (formerly Lower Bowen Volcanics) near the base of the Permian succession on the south - eastern flank of the Bowen Basin. In addition to andesite, the formation includes andesitic agglomerate and tuff, dacite, trachyte and rhyolite. It is estimated to be 12,000 ft thick (Denmead, 1938). The andesite is usually porphyritic and light to dark green, brownish green or grey in colour.

The volcanics are conformably overlain to the west by marine and fresh water sediments which strike NNW and dip 250 WSW. Sandstone of Triassic age occurs as thin horizontal outliers on the higher hills in the Cracow area. Usually the sandstone is capped by lateritic material.

The volcanics are intruded by the late Permian Auburn granodiorite, the western margin of which is 4 miles east of the Golden Plateau mine. The granodiorite forms part of the Auburn granitic complex which also includes granitic and metamorphic rocks of pre-Permian age. Granite fragments in agglomerate exposed in the mine are thought to be derived from a pre-Permian intrusion. Bosses of gabbro, diorite and porphyrite, and dykes which are largely rhyolitic and trachytic in composition, also intrude the volcanics. The bosses may be differentiates related to the late Permian period of intrusion, and the dykes end - phase devivatives of the same period of igneous activity.

## III. ORE DEPOSIT

Although several small, isolated deposits occur in the Cracow Field, nearly all the gold production has come from the E - W Golden Plateau lode system which forms a faulted link between the NNW striking White Hope lode on the west and the Golden Mile lode on the East.

An early generation of almost barren quartz is common to all three lodes. The main generation of auriferous quartz, which was evidently introduced between stage 2 and 3, was confined very largely to the highly sheared Golden Plateau lode section.

Prior to ore deposition hig angle thrust faulting took place along the southern side of the Golden Platteau lode system, the south block being upthrown. The Golconda Fault, and the NNW striking fault at the eastern end of the Golden Plateau lode, were probably initiated prior to ore deposition, but post - ore movement has also taken place.

Within the Golden Plateau lode, irregular tabular ore-shoots have been mined discontiuously over a length of 2,275 ft, widths of up to 50 ft, and to a depth of 825 ft. In some sections hanging wall and footwall ore shoots are present. The largest oreshoot has been stoped from the sub - outcrop below the sandstone capping to the 625 ft level, over a length of 160 to 300 ft and an average width of between 15 and 20 ft.

Nearly all the oreshoots in the central and eastern sections of the Golden Plateau lode dip very steeply or vertically, whereas in the western section of the lode they dip southerly at angles of 400 to 750. The pitch of the ore-shoots is vertical or to the west at moderate to steep angles. They parallel or strike at an acute angle to the lode system as a whole.

Near the western and of the mine, below the 425 ft level, is the Hanging Wall oreshoot which differs in several respects from other Golden Plateau oreshoots. It strikes N-S and ranges in dip from 200 W to vertical. In addition, it is situated south of an important shear zone known as the South Wall which marks rhe hanging wall of the Golden Plateau lode west of the Main shaft in the upper mine levels.

Recent diamond drilling by the Queensland Department of Mines located significant gold values beyond the south-western limit of the mine workings. The new ore-shoot has a similar strike to the Hanging Wall oreshoot, but its relationship to the Golden Plateau lode system is not yet fully understood.

## IV. MINERALOGY

Native gold occurs as gold-silver alloy in a quartz gangue. Enrichment of gold was most pronnouced within 100 ft of the surface and silver values were somewhat enriched towards the base of oxidation at the 276 ft level. Most of the gold in the oxidised ore occurred as "paint" or "mustard" gold (Denmead, 1938). Primary gold is seldom visible to the naked eye even in high grade ore. Small amouts of sphalerite, chalcopyrite, pyrite, galena and bornite are sometimes present, and hessite, altaite and argentite ? have been identified in polished sections of ore. Much of the gold is confined to streaks which are narrow, linear and asually traceable only over short lengths.

Since primary ore has been mined, the gold: silver ratio indicated by the annual production figures has ranged from 1:07 to 1:1.9. Erratic variations in gold: silver rations are indicated by assays of face samples. In ore stope No. 2B West, near the eastern of the

No. 1 oreshoot above No. 3 level, silver values were so high that is was referred to as the "Silver" stope.

From a fineness of 970 in the amalgam bullion from oxidised ore (Denmead,1938, P.407), the figure dropped to 700 to 750 for primary ore has ranged from less than 300 bullion from primary ore has ranged from less than 300 to over 500, indicating an erratic distribution of silver minerals associated with the gold.

Some oreshoots have features such as wavy or concentric banding in the quartz and the presence of pink feldspar (adularia) which can be used as indicators of the presence of gold. In other places gold - bearing quartz and almost barren quartz are indistinguishable. Angular remnents of silicified or propylitized andesite are often present in the quartz and the contact between quartz lode material and andesite may be either sharp or gradational. Although in some places the only macroscopie evidence of wall rock alteration may be the orange-red colour of the feidspar phenocrysts, in thin section the andesite invariably shows the effects of hydrothermal alteration with the development of kaolin, chlorite, pyrite, epidote, calcite and zeolite.

## V. CONTROLS OF MINERALIZATION

Nearly all oreshoots have one wall defined by a fault plane or fault zone. These faults normally mark the hanging wall and may be the only obvious feature controlling gold deposition. In such oreshoots the stope limits on the footwall are determined by assay.

In the eastern section of the mine, oreshoots often occur adjacent to a rhyolite dyke or they may have a fault marking one wall and a rhyolite dyke the other. The area in the acute angle between intersecting faults or well developed joints is also a favourable locus for gold deposition. Flatly dipping faults determine the upper limits of gold deposition in some oreshoots, and elsewhere they have been shown to displace oreshoots laterally.

The main structural control in the North lode oreshoot is a near vertically dipping fault on the southern side. The deterioration in gold values below the 426 ft level is probably related to a change in the dip the fault from 85$^0$ N to 85$^0$S. Similarly, small changes in the strike of the fault may account for the eastern and western termination of significant gold values.

## VI. ORE GENESIS

The Golden Plateau is a hydrothermal replacement deposit. The mineral assemblages and gold fineness suggests that ore deposition took place near the base of the epithermal zone.

Rhyolite dukes exposed in the eastern of the mine exhibit a close spatial relationship to the gold-bearing quartz. No rhyolite dykes are exposed in the western part of the mine but they extend further west on the deeper mine levels. Quartz veins in the rhyolite show that at least some of the auriferous quartz was introduced after consolidation of the rhyolite.

Denmead (1946) observed lode quartz penetrating the Triassic sandstone capping and considered the main period of mineralization to be Jurassic. If the rhyolite dykes are genetically related to the late Permian granitic intrusion, the main period of mineralization may have been late Permian or early Triassic with a minor recurrence in post - Triassic times (Buley, 1953). Jones (1948) considered the gold deposition to be of Middle Triassic age and correlated the Cracow deposits with other mineral deposits in south - eatern Queensland associated with acidic dykes.

**VOCABUARY**

| | |
|---|---|
| To be discoved | Được phát hiện |
| Substantial amount | Một lượng lớn |
| To be conformably overlain | Phủ chỉnh hợp |
| Strike NNW | Phương BTB |
| Dip 25 WSW | Cắm 25° về NTN |
| To be intruded by | Bị xâm nhập bởi |
| Trachytic in composition | Thành phần trachit |
| End-phase deviatives of | Sảnphẩm pha cuối của |
| Barren quartz | Thạch anh không chứa quặng |
| Auriferous quartz | Thạch anh chứa vàng |
| Thrust faulting | Đứt gãy chờm |
| Upthrown | Chờm nghịch |
| Tabular ore-shoots | Trụ quặng, bướu quặng dạng tấm |
| Footwall/Hanging wall | Cánh nằm/cánh treo |
| Streak(v, n) | Sọc, vết |
| Amalgam bullion | Vàng tự sinh/hỗn hống |
| Concentric banding | Dải đồng tâm |
| Polished section | Mẫu mài láng |
| To be determined by assay | Được xác định bằng phân tích |
| Feature controlling gold deposition | Đặc điểm khống chế lắng đọng vàng |
| Acute angle | Góc nhọn |
| Intersection faults | Đứt gãy giao nhau |
| Gold finess | Tuổi vàng |
| Recurrence | Tái diễn, tái sinh, |

# VII.6. TIN AND LEAD ORE DEPOSITS OF ZEEHAN

## I. INTRODUCTION

Although cassiterite deposits of economic importance were discovered at Mt. Heemskirk as early as 1876, the Zeehan district is best remembered as a producer of silver and lead.

The tin boom at Heemskirk lasted from 1879 until 1884 and during that time much money was invested. At least 15 companies installed batteries, and leases were pegged anywhere, even under the sea. But the tin shoots, though sometimes rich, were very small and only about 670 tons of tin has come from the field.

Lead ores were dicovered nearby at Zeehan in 1882. From 1887 to 1897 development was progressive and about 200 lodes were opened up, but attention was paid principally to those with a high silver content and lower grade ores were neglected. The peak of production was in 1896 but it was not until 1898 that smelters were erected. After this production declined and by 1910 there was very little profitable mining. Most of the high grade ore did not persist in depth, in which few workings exceeded 300 ft. In 1913 the smelters closed and the field was practically abandoned until 1950 when th Oceana Mine was re-opened. Between 1954 and 1960, when this mine closed again, 128,000 tons of ore was produced, averaging 11.6 per cent lead and 4.6 oz/ton silver. The field has produced 221,000 tons of lead and 29,000,000 oz of silver.

## II. GENERAL GEOLOGY

The oldest rocks, assigned to the Older Proterozoic, are the Concert Schist (the Davey Group of Elliston, 1954) a formation of sandstone, siltstone and shale, of unknown thickness. These rocks have been coverted by low grade regional metamorphism into a variable suite of quartz schist, quartz-mica schist, sericite schist and graphitic schists occurring in scattered outcrop at Dundas, three miles east of Zeehan.

The Whyte schist, a formation of sericite schist, quartz-mica schist and schistose quartzite outcropping sparsely along the Pieman River and on the coast north of Duck Creek, is of the same age.

Unconformbly overlying these rocks is the Oonah Quaztzite and Slate, consisting of alternating white - weathering pale grey saccharoidal quartzitic sandstone or quartzite, thin-bedded micaceous quartzte and siltstone, and laminated hard greenish grey or black shale. Dark grey limestone and dolomitic limestone occur locally, and spilitic lava flows and pyroclastic bands are found on the upper part of the sepuence. The Oonah Quartzite and Slate is probably at least 7,000 ft thick and is exposed within a complex folded anticlinorium. At Dundas this sequence was described in detail by Elliston (1954) as the Carbine Group.

Succeeding this sequence, apparently conformably, is 10,000 ft of purple and green mudstone, greywacke and slate called the Crimson Creek Formation which in turn passes up into the lithologically similar Dundas Group. The latter consists of alternating slate, coglomerate and greywacke members, with in addition some lavas and tuffs and contains the oldest fossils known in the district. The sequence is considered to be Lower to Middle Cambrian.

The Ordovician Junee Group overlies the Dundas Group and is composed of Mt. Zeehan Conglomerate (0 - 1500 ft) which is equivalent to the Owen conglomerate, the Moina Sandstone (120 - 1000 ft) and the fossil-perous Gordon Limestone (1000 - 2000 ft).

Overlying the Junee Group, probadly disconformably, is the Eldon Group of Silurian to Devonian age. This consists of up to 6,000 ft of Silurian and Lower Devonian siltstones, shales, slates and quartzites. Permian glacial, freshwater and marine sediments lie unconformably on folded Proterozoic and Lower Palaeozoic formations and include the Zeehan Tillite, previously regarded as Precambrian.

## III. IGNEOUS ROCKS

In the late Upper Cambrian, widespread ultrabasic and basic sills and dykes were intruded into the pre-junee sediments. These are all partially or completely serpentinized. At Trial Harbour, nickel mineralization occurs in serpentinized peridotite and dunite, which contain irregular bands of magnetite. In the Comstock area 4 miles west of Zeehan, a thick transgressive sill of hornblende gabbro has intruded rocks of the Crimson Creek Formation. The northern part of this intrusion has been partly serpentinized and dolomitized and contains the Tenth Legion Magnetite deposit. A coarse uralitized gabbro also outcrops at North Heemskirk. At Dundas two bodies of ultrabasic rocks, largely serpentinized, intrude the base of the Dundas Group.

The Heemskirk granite complex, which outcrops over an area of 35 aquare miles west of Zeehan, is a large stock intruded during the Devonian near the southern limb of an anticlinorium of Proterozoic slate and quartzite. The most common variety is a coarse holocrystal - line pink adamellite composed of pink orthoclase, quartz, and albite or oligoclase with some biotite. A finer grained white granite which merges into this without sharp contact lacks pink orthoclase but contains abundant tourmaline, often as quartz-tourmaline nodules. This is known as tin granite as most of the tin depositns are associated with it. Dykes and veins of porphyritic microgranite, aplite, pegmatite and greisen often traverse the adamellite and tin is often associated with these.

## IV. STRUCTURAL GEOLOGY

There are no major angular unconformities from Upper Proterozoic to Devonian. The major structures have been produced by the Devonian Tabberabberan Orogeny and by post-

Permian epeirogenic blockfaulting. The principal fold axes strike NW. with variable plunge and the strata often show marginal faults and E-W cross folding. Intense faulting accompanied this folding, but it is not always possible to distinguish original Tabber - abberan faults from those of Jurssic and Tertiary age, as movement has often taken place in these later periods along old zones of weakness.

## V. MINERALIZATION

Minor iron and nickel ore deposits, mentioned above, are associated with the Upper Cambrian ultrabasic intrusions The important mineral deposits of the Zeehan region are tin and lead ores occuring within and near the margin of the genetically associated Devonian Heemskirk Granite. Four main types of mineral as sembledges, zonally arranged about this granite, were early recognized between the granite margin and Zeehan about 4 miles to the east.

In the granite cassiterite is the important mineral, with associated tourmaline, quartz, pyrite and arsenno-pyrite, and some chalcopyrite, sphalerite, galena and tetrahedrite near the south-eastern margin of the granite. Bismuthinite, wolframite and molybdenite are rare. Some cassiterite occurs in the contact aureole, and, generally further out from the granite, some pyrrhotite, pyrite, chalcopyrite, sphalerite and galena. The Tenth Legion magnetite body in this zone, previously considered a Devonian contact metasomatic deposit, is now thought to be an Upper Cambrian deposit formed as a segregation in the ultrabasic intrusions.

Weak copper minerlization cocurs north of this, while eastwards it grades into a third zone with sphalerite generlly more abundant than galena in a gangul of pyrite and quartz. Further east, the amount of sphalerite decreases, and the mineralization passes into the anti-mony- and siver-rich galena-tetrahedrite ores in a siderite gangue, with minor pyrite, chalcopyrite and sphalerite, which occur at Zeehan.

These zones grade from one ore type to another, and tin is occasionally present in all zones, as at the Oonah Mine, in the outermost zone, where stannite was the main sulphide, with some earlier cassiterite, in a vein about 250 ft from a vein rich in galena.

The tin lodes consist of quartz-tourmaline-cassiterite fissure veins, some bounded by greisen which may contain as much cassiterite as the central vein, and less commonly as pipes of stanniferous greisen which are .

## VOCABULARY

| | |
|---|---|
| Boom | Nổi tiếng |
| Leaseswere peged anywhere | Các hợp đồng đã được cắm ở khắp nơi |
| Were erected | Được xây dựng |

| | |
|---|---|
| Assign to | Cho là, ấn định |
| To be converted | Bị biến đổi |
| Sparsely | Thưa thớt, một cách rải rác |
| Unconformablely overlying | Phủ bất chỉnh hợp |
| Alternate (v) | Xen lớp, xen kẽ |
| Laminated (adj) | Phân phiến, phân lớp |
| Spilitic lava flow | Dòng lava spilit |
| Complex folded anticlinorium | Phức nếp lồi |
| Sequence | Lớp, phân vị địa tầng |
| Mudstone | Sét kết |
| Greywacke | Grauvac |
| Lithologically similar | Tương tự về thạch học, giống nhau về đá |
| To pass up = To give up | Từ bỏ |
| Disconformablely | Bất chỉnh hợp, trái khớp |
| Glacial sediment | Băng tích |
| Freshwater ~ | Trầm tích lục địa |
| Marin ~ | Trầm tích biển |
| Nickel mineralization | Khoáng hoá niken |
| To be serpentinizaed | Bị secpentin hoá |
| ~ dolomitized | Bị đolomit hoáhoá |
| Sill | Vỉa xâm nhập |
| Dyke veins | Các mạch đai cơ |
| Angular unconformity | Bất chỉnh hợp góc |
| Orogeny | Sự tạo núi |
| Epiorogenic block faulting | Hoạt động đứt gãy sau tạo núi |
| Fold axes | Trục nếp uốn |
| Marginal fault | Đứt gãyven rìa/ranh giới |
| Mineral assembldge | Tập hợp khoáng vật |
| Tin | Thiếc |
| Silver | Bạc |
| Boom | Phất, nổi tiếng |
| Leases were pegged anywhere | Các hợp đồng đã được cấm ở mọi nơi |

| | |
|---|---|
| Were erected | Đã được xây dựng |
| To assign to | Ấn định, cho là |
| To be converted | Bị biến đổi |
| Schist | Đá sừng |
| Shale | Đá phiến sét |
| Sparsely (ad) | Một cách rải rác, thưa thớt |
| Unconformably overlying | Phủ bất chỉnh hợp lên |
| Alternating | Xen lớp, xen kẽ |
| Laminated (adj) | Phân phiến, phân lớp |
| Spilitic lava flows | Các dòng lava spilit |
| Complex folded anticlinorium | Phức nếp lồi |
| Sequence | Phân vị địa tầng,lớp |
| Mudstone | Đá bùn kết, sét kết |
| Greywacke | Grauvac |
| Slate | Đá phiến |
| To pass up | Từ bỏ/từ chối |
| Lithologically similar | Tương tự về thạch học, giống nhau về thạch học |

## VII.7. LEAD-ZINC ORE DEPOSITS OF BULMAN

### I. INTRODUCTION

The deposits occur in an area of low relief in the broad valley of the Wilton River in southern Arnhem Land, 40 miles north-east of Mainoru station homestead at lat. $13^0 40$ S, long. $134^0 18'$ E. Access is by 200 miles of road from Katherine. Flat-lying Proterozoic rock form low hills and ridges surrounded by black soil and alluvium.

The field was discovered between 1908 and 1911 and about 10 tons of ore were mined from shallow shafts and pits, but the field was abandoned because of low lead values which, in spite of impressive surface showings of galena, average no more than 2 per cent beneath the surface. Interest was revived when a prospector Harold Brennan obtained some specimens in 1951. Consolidated Zinc Pty Ltd carried out exploration work in the field intermittently from 1952 onward.

### II. GEOLOGY

Host rock is the Dook Creek formation of flet to gently dipping dolomite, limestone and chert belonging to the Mt. Rigg Croup of Lower Proterozoic age. It is underlain to the north by Lower Proterozoic sandstone of the Bone Creek formation and overlain to the south by Upper Proterozoic sandstones and siltstones of the Ropoer Group. None of the beds above or below the Dook Creek formation are known to be mineralized and do not cocur in the area covered by Fig. 1. Correlation of the host formation of the Bulman deposits with that of the McArthur River lead-zinc deposits 220 miles to the south-east was suggested as early as 1952, was supported by reconnaissance mapping in 1957 (Patterson, uppublished data) and confirmed by recent mapping by the Bureau of Mineral Resources.

The host formation is locally about 1000 ft thick, comprising an upper limestone 50 ft thick overlying a dolerite sill 370 ft thick, a lower limesttone 450 ft thick, a second doletite sill and limestone. The algal form Collenia is common in the carbonate rocks, but does not form large scale reefs.

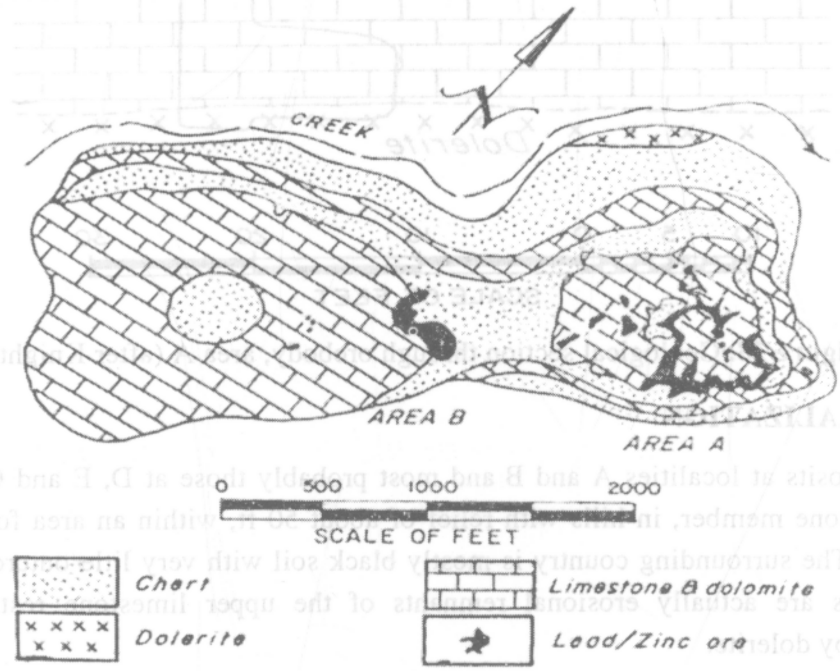



**Figure 27.** Geological plan of Bulman deposit (after Knight).

A prominent system of joints is developed on a regional scale, the main trends being north-east and north-west. The Bulman Fault traverses the area, although it is concealed, except in the north-western corner of the plan. This fauit, in common with most of the others, has little or no displacement, but it is a major feature traceable for almost 200 miles. Campbell (1956) pointed out the alignment of the Bulman Fault with the southern coast of the Gulf of Carpentaria. There are no plutonic intrusives and metamorphism is lacking, except for a narrow zone a few inches wide at the limestone-dolerite contact (Figure 27).

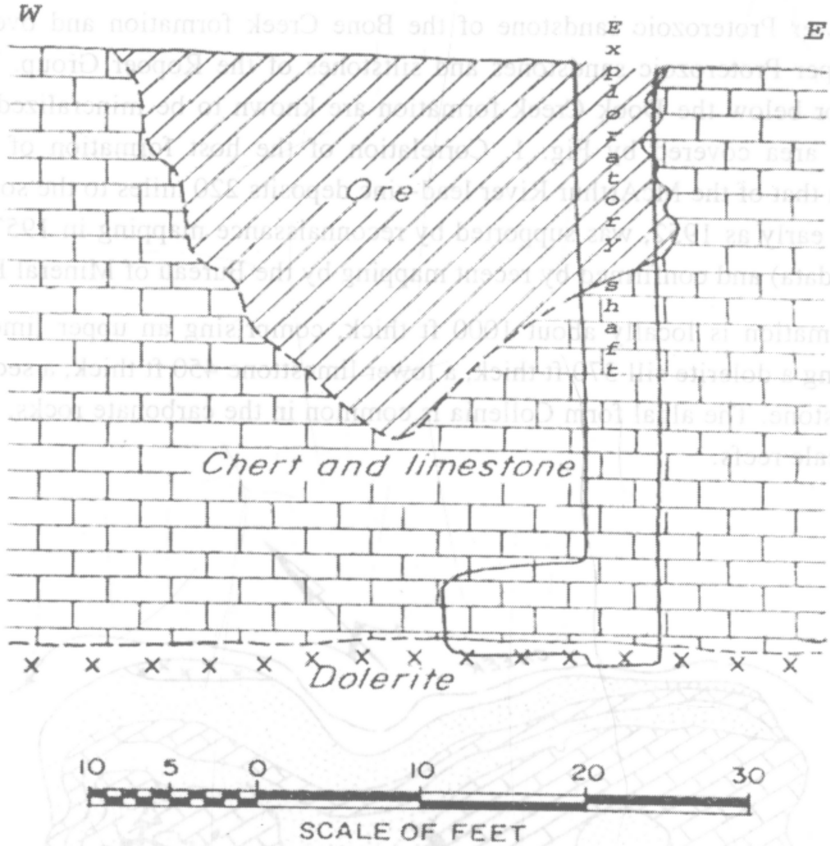



**Figure 28.** Geological section through orebody, area A (after Knight).

## III. MINERALIZATION

The ore deposits at localities A and B and most probably those at D, E and G are in the upper limestone member, in hills with relief of about 50 ft, within an area four miles by four miles. The surrounding country is mostly black soil with very litle outcrop. The ore-bearing hills are actually erosional remnants of the upper limestone resting on and surrounded by dolerite.

At A, B, D, E and G, with the exception of two or three insignificant horizontal seams of massive galena, only oxidised ore was found. It consists of cerussite and galena, hydrozincite, smithsonite and willemite and occurs in lodes of two general types.

1. In a high zinc crust type, the mineralization beneath the cap is light coloured calcareous mateial averaging about 20 per cent Zn and 3 per cent Pb, well bedded, with bedding warped, tilted and broken to some degree but essentially horizontal. Commonly one wall of a shoot is a straight fracture outcrop.

2. In a cherty cap type, grade is appreciably lower bedding planes are tilted and broken and blocks of type 1 ore are enclosed.

The lodes form an interconnecting system reminiscent of some Tri-State USA deposits. They narrow downward and bottom at shallow depth. Boundary between ore and the enclosing rocks is sharp. Knight (1952) considers the lodes represent sulphide bodies oxidised in situ, whereas King (1953) inclines to the view that they are largely or wholly secondary concentrations.

Ore distribution and the shape of the orebodies may have been influenced by the prominent joint system, for it is evident that this feature has been an important factor in the shape of outcrops generally.

At locality F a small high grade lead lode was found in the top of the lower limestone member. A drill hole close to the lead lode intersected appreciable amounts of sphalerite and galena in four narrow zones between 40 and 150ft. Three drill holes close by intersected weakly disseminated galena and pyrite only.

The ratio of zinc to lead is generally lower in the sulphide zone than at the surface. Assays of sulphide ore consisting of light brown (low iron) sphalerite and galena from a drill hole on Area F indicate an average zinc: lead ratio of 3:1. Silver content is usually less than 1 oz/ton. Copper is present as showings of malachite on Areas A and F and was seen as traces of chalcopyrite with lead- zinc sulphide ore in drill core from Area F.

Pyrite is common throughout the limestone and occasional isolated specks of galena, but rarely sphalerite occur. Manganese occurs as superficial cappings of psilomelane and pyrolusite on chert and limestone. It appears to be more common along fault lines, several minor manganese occurrences having been noted along the Bulman Fault.

It would appear that mineralization, apart from the Area F occurrence, is confined to the upper limestone. However, this may be due in part to the upper limestone. However, this may be due in part to the upper limestone having been more deeply eroded and also possibly to secondary enrichment processes associated with this erosion. Prospecting, including geological mapping by Campbell (1956) of a 700 square mile area, and geo-chemical sampling of the same area in 1961, has not indicated any new ore occurrences. Soil sampling around Area F suggests a geochemical zinc halo and some stream dispersal of both lead and zinc was observed near known ore occurrences.

## VOCABULARY

| | |
|---|---|
| Lead-zinc ore deposit | Mỏ quặng chì- kẽm |
| Homestead | Đất trang trại |
| Ridge | Rặng núi, dãy núi |
| Shaft | Hầm lò, giếng mỏ |
| Pit | Giếng thăm dò, khai thác lộ thiên |

| | |
|---|---|
| Prospector | Người tìm kiếm/thăm dò |
| Chert | Đá sừng, đá phiến silic |
| To be supported by reconnaissance mapping | Được sáng tỏ bằng đo vẽ BĐĐC |
| Algal | Tảo |
| System of joint | Hệ thống khe nứt |
| To traverse | Xem xét toàn bộ; đi qua |
| Traceble (adj) | Có thể they/ dấu vết |
| To be concealed | Bị che khuất/ bị phủ |
| Erosionnal remnant | Di tích xâm thực |
| Alignment (n) | Sắp hàng |
| Seam | Lớp kẹp, vỉa |
| Well bedded | Phân lớp rõ ràng |
| With bedding warped | Vỉa, lớp bị uốn cong/vò nhàu |
| To be tilted | Bị nghiêng |
| Straigh fracture outcrop | Vết lộ đứt gãy thẳng |
| Reminiscent (adj) of | Gợi lại/ nhớ lại |
| To incline to the view | Nghiêng về quan điểm |
| Shape of the orebody | Hình dạng thân quặng |
| Assay | Phân tích mẫu/ thử nghiệm |
| Specks | Đốm, ổ nhỏ |
| Secondary processes | Quá trình thứ sinh |
| Geological mapping | Đo vẽ BĐĐC |
| Geochemical sampling | Lấy mẫu địa hoá |
| Soil sampling | Lấy mẫu thổ nhưỡng |
| Halo | Vành phân tán |
| Stream dispersal of | Dòng phân tán của... |
| To be observed | Được phát hiện |

## VII. 8. BROWN'S LEAD ORE PROSPECT, RUM JUNGLE

### I. INTRODUCTION

Copper mineralization was reported from an area near Rum Jungle siding, about 60 miles south of Darwin, prior to 1907. A few shallow pits excavated at the site came to be known as the Rum Jungle Copper Mines.In 1913, the Northern territory Administration on behalf of a Western Australian mining company tested the occurrence by two diamond drill holes but results were discouraging and the prospect was abandoned. There is no record of any further activity in the area until 1949 when uranium was discovered at the present site of White's open cut, about one mile to the east. At this stage the area was renamed Brown's Prospect.

In the subsequent intensive search for uranium in the Rum Jungle area, considerable attention was focussed on Brown's Prospect as one of the potentially favourable areas for uranium ore occurrence. The discovery of traces of torbernite in association with secondary copper mineralization together with positive geophysical indications in the form of a radiometric anomaly and two self-potential anomalies provided encouragement for subsurface testing. Following a campaign of trenching and shaft sinking to shallow depths a programme of drilling was commenced in 1952.

This later exploratory effort failed to reveal any uranium of consequence within the limits of testing but the drilling did reveal significant amounts of lead mineral-ization with some copper over an appreciable strike length.

In 1956, Consolidated Zinc Pty Ltd recommenced testing of this mineralization as a base metal prospect and by diamond drilling has delineated a substantial, though presently uneconomic, body of low to medium grade lead mineralization extending over a length of some 300 ft and to a depth of 1200 ft.

## II. GENERAL GEOLOGY

Owing to a low topographic relief and an extensive soil cover, the surface expression of the mineralized zone and the enclosing rocks is exceedingly poor, the only exposures bring the feeble showings of copper mineralization in slates and schists at the eastern extremity of the zone. Extensive trenching was necessary to determine the limits of the mineralization and to provide a concept of the geological environment. Later soil sampling in concealed areas showed that a broad indication of the nature and extent of the occurrence could have been obtained by geochemical methods.

The lithological sequence at Brown's Prospect consists of dolomitic limestone, intercalated black shaly sediments of various types, and maphibolite containing narrow bands of shaly material. Elsewhere in the Rum jungle district the dolomitic limestone is overlain by a zone of predominantly chloritic rocks but this unit has not been recognised at Brown's.

Throughout its extent, the dolomitics limestone shows considerable variation in composition and texture ranging from a grey sandy dolomite to a creamy, coarsely crystalline marble, in places containing spherules of hematite.

The overlying sequence of black shaly sediments closely resembles that exposed in White's open cut and consists mainly of grey and black sericitic slates and phyllites with lenses of graphist, andalusite schist, and green and white talcose and chloritic slates and schists.

The andalusite schist is identical with that at White's, exhibiting a well-defined banding and slip-strain cleavage.

South of and overlying the shaly sequence is a very broad zone of amphibolite which is entirely concealed by soil. As seen in drill core, the amphibolite is a massive to well banded, green basic variety, highly calcareous in places and containing erratically distributed patches of iron sulphides and minor sphalerite. Intercalated with the amphibolite are narrow bands of dense, pyritic black slate and chloritic schist. A very broad and intense magnetic anomaly recorded over the amphibolite zone apparently is due mainly to the pyrrhotite content.

The main host rock for the lead mineralization is a well banded grey sericitic phyllite with a characteristic silky lustre; copper mineralization is usually most abundant in the more strongly graphitic rocks, especially in the eastern portion of the zone. The ore minerals are not confined to these rocks however, as lenses of talcose, chloritic rocks within the lead- and copper-bearing sequence may be mineralized to the same degree as the black shaly sediments though the sulphide minerals do not appear to be as uniformly distributed in these horizons.

## III. MINERALOGY

In the oxidised zone, wich extends to 50 ft, and in some place to 75 ft depth, the predominant ore minerals are cerussite and malachite while anglesite, pyromorphite, azurite and cuprite are minor components. In the sulphide zone the chief constituent is galena which is usually very fine - grained, often occurring as smears on cleavage planes. Chalcopyrite and sphalerite are minor components, the former being most abundant at the north-eastern end of the zone but subordinate to sphal-erite at the south-western end. The presence of linnaeite in most polished sections accounts for the small cobalt content of the body. Covellite, boenite, digenite and pyrrhotite are present in trace amounts (Williams, 1956, 1957).

Mineragraphic studies place the paragenetic sequence as pyrite, followed by linnaeite, chalcopyrite and sphal-erite, with galena, which replaces all four, being the last to form.

While much of the lead mineralization has been sheared out along cleavage planes, some galena occurs as fine-grained crystals in interlacing veinlets, often with an enclosing quartz gangue. The more brittle minerals pyrite and chalcopyrite have shattered in response to shearing stress.

Chalcopyrite occurs principally as fine stringers and veins but also has been noted in more graphitic sections as irregular coarse blebs. Some polished sections show a mixture of digenite and covellite as an alteration halo around chalcopyrite. Traces of bornite have been reported from the eastern cupriferous section of the zone.

Linnaeite is generally associated with galena, by which it has been replaced, but is also found as inchusions in chalcopyrite and pyrite.

Sphalerite is intimately associated with gelena and to a lesser extent with chalocopyrite, occurring mainly as fine veins. At the western, zincy end of the mineralized zone cream coloured sphalerite occurs sporadically in coarse veins.

## IV. STRUCTURE

The mineralized zone occurs within a sequence of metamorphosed black shaly sediments, along the south-westerly extension from White's open cut of the stratigraphically favourable slate-limestone, which is the host environment for the bulk of the mineralization in the Rum jungle (Thomas, 1956, 1958). The strike of the zone is NE and the dip varies from flatly south to near vertical or vertical in the south-west portion. Drilling has disclosed that the mineralized zone is essentially a tabular, conformable body varying in width from about 40 to 160ft, the maximum width and also the highest lead values being in the central portion.

At the surface, east of the central portion of the zone, there is evidence of pronounced warp in the strike while a short distance to the west is a sharp change in the dip from about 350 S to 900 at 150 ft depth. However, neither of these features appears to have exerted any influence on the localization of mineralization. Zones of contortion and crenelation qith superimposed shearing are common throughout the shaly sequence and are not confined to the mineralized zone.

Parts of the mineralized zone are brecciated and there are also indications of minor post-ore faulting in drill core. The irregular trend of the limestone-slate contact may be evidence of a pattern of step-faulting or, perhaps, large-scale drag-folding but the pattern is not reflected in the mineralized zone.

The prominent "Main Shear" zone at White's open cut which, by projection, should pass through Brown's Prospect, possibly between the mineralized zone and the amphibolite, has not been recognised with certainty and there is little direct evidence to suggest that the mineral-ized zone is truncated in depth by any equivalent of this shear zone, as is the case at White's.

The outstanding features of the structural setting are the rapid convergence of the mineralized zone on the limestone along strike and dip.This can be explained as being due to rapid lensing of the inter-vening sediments; changes of this kind are not un- common in the Rum Jungle district.

## V. DISTRIBUTION OF MINERALIZATION

A study of the distribution of lead values shows that it is possible to divide the mineralized zone into three lenticular bands. These comprise a footwall, a hanging wall band of similar grade, and a third, lower grade band which, throughout its extent, separates the other two.

This interpretation of the internal distribution of mineralization satisfactorily explains the variation in thickness of the mineralized zone as being due to the thickening or thinning or lensing out of one or more of these three bands.

However, a study of the distribution of lead values in relation to lithology reveals that the internal grade contours do not always follow stratigraphic boundaries or lothologic contacts but frequently transgress them which conflicts with both margins of the mineralized zone conforming to the bedding of the enclosing sediments.

## VI. GENESIS

In the absence of any detailed knowledge of mineral distribution in relation to lithology, due mainly to the lack of underground development, little signigicance can be attached to this apparent discrepancy, especially in retation to the contentious problems of origiin and mode of formation of the deposit.

The only conclusion which may safely be drawn from the results of drilling at Brown's Prospect is that the mineralized zone, as a whole, is a stratigraphically disposed body which shows the effects of later shearing stresses.

In the broader view, the mineralization at Brown s, like that in the other known occurrences of the district, is intimately related to a particular sedimentary environment. The evidence supports the view that the deposits form an integral part of that environment and are of contemporaneous sedimentary origin.

## VOCABULARY

| | |
|---|---|
| Discouraging | Thất vọng |
| Prospect was abandoned | Vùng triển vọng bị loại |
| A campain of trenching & shaft | Chương trình đào hào và giếng |
| Secondary copper mineralization | Khoáng hoá đồng thứ sinh |
| Radiometric anomaly | Dị thường xạ |
| Mineralized zone | Đới khoáng hoá |
| Enclosing rocks | Đá vây quanh |

| | |
|---|---|
| Concealed areas | Vùng bị phủ |
| Reveal (n,v) | Phát hiện, bộc lộ |
| Has delinated sth | Thể hiện, phác thảo |
| Owning to: Do, nhờ có | Bleb: bọt khí |
| Surface expression of | Biểu hiện bề mặt của |
| Exceeding poor | Quá nghèo |
| Lithological sequence | Loạt thạch học, tập hợp đá |
| Slipstrain cleavage | Thớ chẻ ứng suất giả |
| Erratically distributed patches | Các ổ, đám phân bố không dều |
| To be entirely concealed by soil | Hoàn toàn bị đất phủ kín |
| Intercalate (v) | Xen kẽ |
| Silky luster | Ánh tơ |
| Smear | Đốm bẩn, hoen ố |
| Subodinate (v,adj) | Phụ, dưới |
| Zone of contortion | Đới vò nhàu |
| Crenelation(n); Crenelate (v) | Tạo lỗ |
| Drag-faulding | Đứt gãy kéo theo; đứt gãy oằn |
| To be truncated | Bị gián đoạn; bị cắt cụt |
| Convergence | Hội tụ, đồng quy |
| Interveining sediment | Trầm tích xen |
| Transgress | Biển tiến |
| Apparent discrepancy | Khác nhau rõ ràng |
| Contentious problem | Vấn đề bàn cãi, tranh luận |
| Intimately (adv) | Một cách sâu sắc |
| Intergral part of | Một phần cấu thành của |
| Contemporaneous | Đồng thời |

## VII.9. COPPER - GOLD ORE DEPOSIT OF MOUNT MORGAN

### I. INTRODUCTION

The Mount Morgan Mine, a major producer of gold and copper for over 80 years, is 23 miles SSW of Rockhampton. The orebody, discovered in 1882, forms part of a hill rising approximately 500 ft above the Dee River, and originally 1,275 ft above sea level.

After almost 41 years of continuous operations, during which the Mount Morgan Gold Mining Company treated 9,307,638 tons of ore containing 5,345,000 oz of gold and 140,000 tons of copper, mining ceased in 1925 owing to a disastrous fire which led to the flooding of the underground workings.

Mount Morgan Limited has to June 1964 treated 24,447,656 tons of ore yielding 1,728,477 oz of gold and 151,224 tons of coper, bringing the total production of ore to 33,755,294 tons for a yield of 7,073,477 ounces of gold and 291,224 tons of copper.

A substantial quantity of material originally classified as overburden has proved to be low grade ore warranting treatment for its gold and copper content. The ore reserves at June 1964 are estimated as 10,155,000 tons averaging 2.34 dwt/ton gold and 1.10 per cent copper.

## II. REGIONAL GEOLOGY

The Mount Morgan orebody occurs within an NNW - SSE elongate roof of volcanic and sedimentary rocks known as the Morgan Formation which lies between the Town Granite to the east and the Mount Morgan Granite to the west.The orebody is in an embayment in the Mount Morgan Granite.

The Morgan formation is thickest in the vicinity of the orebody, thinning south- east to a series of discontinuous outcrops in the Town Granite. Its dominant rock types are rhyolitic tuffs and flows, with lessr rhyolitic agglomerates and some andesites bedded fine - grained chert and occasional lenticular limestones.

The Town and Mount Morgan granite intrusions obscure the relation of the Corridor rocks with nearby Devonian rocks. However regional evidence supports the belief that the Corridor rocks occur at the base of the Middle Devonian Dee Volcanics (Maxwell, 1953). To the west and north-west of the mine the Cretaceous Razorback Beds (Staines, 1952) of unmetamorphosed fresh water sediments unconformably overlie Corridor Rocks, Dee Volcanics, and granites.

The Corridor Rocks away from the mine and, to a lesser extent, the Dee Volcanics are faintly mineralized and the felsite and andesite rocks invariably contain up to 1 per cent of disseminated pyrite but only trace pyrite is found in the quartz porphyry. The Razorback Beds are unmineralized except for a minor gold occurrence in the thin basal conglomerate at Mount Victoria approximately 2 miles south - west of the mine.

## III. MINE ENVIRONMENT GEOLOGY

The chief rock types at the mine are quartz porphyry, "felsite", andesite, chert, jasper and limestone. The regional trend is north - north - east with easterly dips varying from 200 to

800 . The broad lithological succession from east to west, and down the sequence of the regional easterly dip continues, is:

1. Quartz porphyry with some felsite horizons, as in the area around No. 2 Mill pyrite tailing dam,

2. Andesite or basalt, which outcrops along the Dee River east of the general office and to the north - north - west under No. 2 Mill, thence along the east side of Linda Gully (similar rock is along the Dawwson Valley Railway south of the general office and to the north - west around the workshops area),

3. Quartz porphyry, strongly brecciated at the base and becoming somewhat finer up section, well exposed around the eastern and north-eastern sides of the open cut.

4. Well banded siliceous and jasper beds outcropping around No. 3 Bench on the eastern side of the open cut where they dip at 700 to 800 E then flatten to 450 near the smelter stack, 300 past the work - shops, and 200 north of the general office,

5. "Felsite" and some quartzporphyry which are completely gradational in many places.

"Felsite" is described by Staines (1952) as "a number of similar rock types which which are greenishgrey in colour and have a very fine - grained or stony texture". This suite, which outcrop on all benches of the open cut, and is the host rock for the orebody, consists of interbedded spherulitic "felsite" and felsite with limestone, porphyritic "felsite" and quatrz porphyry.

Small isolated lenticular limestone beds are associated with (3) and (5) and one large body occurs on the 850 ft level. The limestone generally has been partly silicified and metamorphosed.

The tuff layer (4) and "felsite" layer (5) reflect a quieter phase of volcanic activity. Fine tuffs, some flow rocks, and siliceous chemical precipitates, exhibiting rapid lithological variation, have been deposited under marine conditions. The overlying brecciated quartz porphyry rhyolitic breccia, tuffs and flow rocks indicate a renewed outburst of volcanic activity. The environment may not have been submarine during the entire depositional cycle. Banded tuffs indicate an aqueous environment with ample time for settling. Some of the infrequent limestone lenses in the area are localized near the base of the Brecciated quartz porphyry and may indicate shallowing conditions and possible emergence during the deposition of the bulk of the quartz porphyry sequence.

Diamond drill cores show that below the Linda Fault there is lithological similarity of rock types to those above but no evidence of the same degree of fracturing.

Except in the quartz - pyrite mass, pyritization (1 to 5 per cent) is higher in the rocks close to the mine, but its distribution is irregular.

## IV. FOLDING

Fraser (1914) considered the structure of the mine area to be simply that of easterly dipping beds, while Reid (1947) postulated the existence of a faulted asymmetrical anticline. Conolly (1952) considered the mine structure to be two dome-like arches in conjunction with two complementary troughs resulting from thrust.

The strikes and dips of the banded siliceous tuffs on the hanging wall side of the Slide Fault point to the possibility of an anticlinal structure with the axis striking NW. However, in the south- east corner of the open cut this marker bed continues to the south- east instead of folding around to the west as would be anticipated with an anti- clinal structure.

## V. FAULTING

The Mine area has been faulted at various intervals and although jointing and small scale fracturing are ubiquitous, there are two dominant fracture directions striking NW and NNW.

The Slide, a pre-ore fault, follows a north-north-easterly course, dipping at $45^0$ to $75^0$ SE, and is a major fault within the orebody. Associated with it is a system of parallel fractures which make a shattered zone 50 to 100 ft in width. There are two known post-ore movements on the Slide Fault, the first displacing the orebody appoximately 200 ft upwards and 220 ft horizontally to the south-west on the footwall side. A series of dykes intruded subsequent to this movement illustrate the second and reverse movement on the fault plane. They have been displaced horizontally 40 ft to the north-east on the footwall side of the fault.

According to Fraser (1914) the oldest fault of the area is the Linda fault. He reported this fault as outcropping along Lida Gully. These exposures are no longer available for inspection. The position of the linda Fault has been inferred from numerous drill holes and in the Sugarloaf and Norgan Extended Shafts. The inferred plane strikes roughly NW, dips at a flat angle SW, and rorms the limit of quartz-pyrite mineralization. The rocks below the Linda Fault do not exhibit the high degree of fracturing that is apparent in the overlying country, indicating the likelihood of it being a thrust plane above which the country has been ruptured by forces operating from the south-west.

The Footwall Shear is a narrow zone of crushed rock in sharp contact with the overlying quartz pyrite and ore; it strikes NW, becoming arcuate to the south-east where it swings rapidly from $135^0$ to $200^0$ and is last seen in the south-east corner of the open cut. Between the 400 ft level and the 1050 ft level the fault dips $45^0$ to the south- west. Above the 400 ft level it branches, the main fork being almost vertical for the short distance over which it can be traced before reaching the present surface. In places along the Footwall Shear is a pronounced cut off between ore and virtually unmineralized country rock. This cut off has been inferred on the Linda Fault in the bottom levels of the mine.

Along the south benches of the open cut there is a series of steeply dipping discontinuous shear planes striking approximately NW, parallel to the footwall shear. Some movement is evident on the fractures, but is probably minor because no one fracture can be traced for more than 200 ft along the strike. It is possible that the cumulative effect these parallel fractures had some control on mineralization to the south.

## VI. MINERALIZATION

The Mount Morgan orebody, including the Sugarloaf orebody, is an irregular quartz pyrite mass. The original outcrop of the main deposit was a strong limonitic gossan approximately 900 by 500 ft, forming the peak of the mountain. At the 286 ft level (No. 2 bench of the open cut) the orebody increased to an irregular area approximately 1080 by 800 ft. Including the Sugarloaf orebody it is now known to have a maximum length of 2100 ft in a ENE direction on the 650 ft level, with a maximum NNW width of about 900 ft.

The approximate dimensions of the main Mount Morgan mineralized mass are 1900 ft long, 600 ft wide and 600 ft deep, the Sugarloaf mass being 1100 ft long 300 ft wide and 400 ft deep. The decrease in size upwards from the 450 ft level to the surface and the absence of any important amount of alluvial in the Dee River indicates that the orebody did not originally extend fer above its outcrop.

The orebody has a sharp boundary only in the north-east. It is elsewhere enclosed in an envelope of low grade quartz pyrite and is gold enriched in the upper portions and copper-rich at lower levels with a decrease in values of both metals from the centre of the mass outwards.

Conolly (1952) estimated the complete mineral mass to originally have contained 65,000,000 tons of quartz pyrite containing 4.00 dwt/ton gol'd, 0.60 per cent copper and 12 per cent sulphur.

A series of contour plans of gold and copper values show the main Mount morgan ore-shoot emerging as a pipe- like body with its largest lateral dimensions in the near vertical portion between the surface and 500 ft depth; then it flattens westward to near horizontal over its central section east of the Slide Fault; finally it turns over steeply and possibly terminates on the flatly disposed Linda fault upthrown west of the Slide Fault. The contouring indicates that, although local variation in values particularly of gold are common, the overall distribution is less erratic than previously suggested. There is a fairly regular decrease in values from the core of the shoot to the perimeter.

Surrounding the original outcrop of the main deposit and capping the adjacent Sugarloaf Hill, Osborne's Knob and callan's Knob was a weakly leached ironstone termed by Conolly "false gossan". The "false gossan" is the surface expression of felsite rocks containing approximately 1 to 5 per cent pyrite, slightly greater than the regional average for rocks of this type, so some is presumed to have been derived from the mineralizing solutions which formed the orebodies.

Not much true gossan appears to be in the Sugarloaf area as oxidation barely reached the top of the quartz pyrite mass. Where irregularities in the top of the quartz pyrite extend into the oxidised zone, the pyrite has been completely leached. Some exposures over the Sugarloaf mineralization are iron-stained kaolinitic and siliceous material which in places can still be recognized as felsite or porphyritic felsite.

Very minor occurrences of malachite azurite, chalcanthite, cuprite andnative copper have been recorded in the true gossan but there is no major concentration to form an oxidized copper orebody.

There are two varieties of pyrite a "normal" pyrite containing numerous zoned silicate inclusions and a second paler much harder variety. This clear lighter coloured pyrite has been explained either as containing a small amount of cobalt or nickel or as an intermediate stage of a change from pyrite to marcasite. In its present form this latter mineral cannot be identified as marcasite.

## VII. LOCALIZATION AND ORIGIN OF THE ORE

Numerous theories have been advanced for the origin of the Mount Morgan and Sugarloaf orebodies and all have one common feature - an epigenetic hydrothermal source. No proof has been offered of the association between the mineralization and a particular magmatic source rock, which remains open to conjecture. Conolly (1952), Hawkins and Whitche (1961) considered that the ore solutions were devived from the granite and emplaced at a late stage of consolidation of the granite magma.

Following their study of the mine area, Hawkins and Whitcher presented the following facts:

1. The mineralizing solutions have been emplaced in a localized zone of shattered rhyolitic rocks.

2. Faulting and shearing have played a major role in limiting the migration of mineralizing solutions.

3. There is a preferred orientation of the mineralized mass in two directions, along the slide fault, and almost at right angles to the slide fault.

4. Where the flow of mineralizing solutions has not been inhibited by a fault plane there has been a fading out of pyrite.

5. The mineralizing solutions were essentially silica and iron sulphide with small amounts of gold and copper. At least two waves of mineralization, of necessity almost contemporaneous, can be determined. The first was a silica-gold wave while the second was rich in copper.

They suggest that feature 4 could be a function of the intensity of fracturing which in turn will govern the permeability of the mass to incoming mineralizing solutions.

Whatever the origin of the mineralizing solutions, some structural preparation of the original host rock is required to permit the permeation of these solutions. All previous workers have utilized tectonic forces associated with the granite intrusion to develop such preparation in the form of large scale fracturing of the rhyolite, rhyolitic tuffs and associated rocks. This premise appears valid. Conolly (1952) and Staines (1953) developed this further by suggesting that a system of troughs and arches were developed, with the orebodies being located in the arch positions. Subsequent drilling and open cut operations have not verified this interpretation. Present evidence suggests that Frazer's (1914) concept of east dipping beds is valid.

## VOCABULARY

| | |
|---|---|
| Substantial amount | Khối lượng vàng |
| Andesitic agglomerate | Cuội kết andezit |
| Are though to be derived from | Cho rằng được thành tạo từ |
| Bosses | Bướu, vòm |
| Igneous cativity | Hoạt động macma xâm nhập |
| Thrust faulting | Hoạt động đứt gãy chờm nghịch |
| Oreshoot | Trụ quặng, bướu quặng |
| Acute angle | Góc nhọn |
| Have been identified | Được xác dịnh |
| Polished section | Lát mỏng; mẫu mài láng |
| Auriferous (adj) | Có chứa vàng, chứa vàng |
| Contouring | Chu vi, đường đồng mức |
| Shattered rhyolitic rocks | Đá riolit dập vỡ, nứt nẻ |
| Slide fault | Đứt gãy tượt |
| Has not been inhibited | Không bị hạn chế |

| | |
|---|---|
| Function of the intensity | Chức năng/ Hàm số của cường độ |
| Have not verified | Không kiểm tra/ xác minh |
| Embayment of | Rìa/ bao quanh của |
| Ubiquitous (adj) | Khắp nơi; ở đâu cũng có |
| Overthrust faults | Đứt gãy chờm nghịch |
| Tensional relief | Địa hình căng; giảm độ căng |
| Be envisaged | Được gắn vào |
| Underground workings | Công trình ngầm |
| Was governed only by | Bị khống chế; bị ảnh hưởng |
| Displacement | Dịch chuyển/Di chuyển |
| Gossan | Vỏ phong hoá/ Mũ sắt |
| To conjecture | Phỏng đoán, ước đoán |

## VII.10. NUIPHAO POLYMETALIC DEPOSIT

### 1. Introduction

The study area is located in the northen part of Vietnam within Daitu district, Thainguyen province. It lies some 80km to the NNW of Hanoi, on the northeast side of the Red River and on the northern side of the Tamdao mountain range. This paper outlines the exploration, development and mineral potential of the Nuiphao polymetalic deposit. Inition exploration was carried out by the Department of Geology and Minerals of Vienam (DGMVN) from1960 until 1992.Exploration by Tiberon Minerals Ltd. Includes regional aerial geophysical surveys, geochemistry, and diamond core drilling.The deposit is currently in the pre-feasibility stage of development where various mining, engineering and processing options are being considered based on the current resource and metal prices.

### 2. Regiona geology and Nuiphao deposit

Large scale geological mapping of the stratigraphy, igneous units and faulting within the area has been taken by a number of workers of the DGMVN and is briefly summarized here.

The Ordovician- Silurian Phungu Formation occurs widely distributed in the central part of the region. It consists of micaceous shale interlayered with sandstone, siltstone, silisified marble, dolomitic marble. This formation has been intruded by the biotite granite of Nuiphao Complex and the two mica granites of Dalien Complex. The Dalien granite is presumed to be late Triassic in age, which outcrops on the north side of the 13A highway, covers an area of approximately 2 $km^2$. This unit is believed to be the main source of the mineralization being investigated.

The dominant regional faulting oriontion is northwest-southeast. According to the DGVN, the 13A National highway fault is regarded as a deep fault separating two tectonic zones. It is interpreted to lie between the Dalien and the Nuiphao granites but field evidence for the fault is scanty. The field evidence for the fault consist of cataclasite and limonite zones and it has likely served as a loci for magma intrusion.

### 3. Mineralization

Both bedrock and placer occurrences of tin are widespread in the region and are found along the margin of Tamdao rhyolite and Truckhe and Nuidieng granitoits. Main occurrences are at Sonduong, Nuidieng and Thienke (Sn-W-Mo skarn). Fracture controlled barite-antimonite mineralization occurs at Lucba and lead-zinc mineralization occurs at Coiky.

Tiberon Mineral Ltd took exploration in the region in 1997 until 2001, at the "Main Gosson" and adjacent to the Dalien granite. Total drilling of 15,074m in103 drill holes for resource delineation and 783m in 11 drill holes for metallurgical sampling. The tungsten bearng mineralization at Nuiphao project is categorized as intrusive related polymetallic greisen and skarn. This skarn and associated greisen-style mineralization are characterized by an assemblage of W-Au-Bi-F-Be bearng minerals that occurs within and proximal to Dalien granite. These metals occur in scheelite, wolframit, native gold, chalcopyrite, native bismuth, bismuthinite, fluorite and danalite.

### 4. Conclusion

A revised resource estimate was completed in Apral 2002 on the Main Gossan, which stands at 24 mt @ 0.39% $WO_3$, 034g/t Au, 0.28% Cu, 0.14% Bi and 10.54% $CaF_2$. The Nuiphao polymetallic skarn/greisen deposit is potentially one of the largest unexploited tungsten and fluorite mines of its kind in the world. The initial economic assessment is positive and the deposit has only been partial explored.

The new discovery indicates thay the Nuiphao polymetallic deposit is potentially one of the largest tungsten and fluorite mines in the world. The project is currently in the pre-feasibility stage of development with on going metallurgical engineering, environmental and economical studies to begin in

## VOCABULARY

| | |
|---|---|
| Inition exploration | Thăm dò sơ bộ |
| Processing options | Các giải pháp chế biến |
| Being considered | Đang được nghiên cứu/xem xét |
| DGMVN | Cục ĐC&KS Việt Nam |
| Phungu Formation | Hệ tầng Phú Ngữ |
| Is presmed | Được cho , coi là |
| Fracture controlled | Đứt gãy, khe nứt khống chế |
| Pre- feasibility stage | Giai đoạn nghiên cứu tiền khả thi |
| Micaceous shale interlayered | Đá phiến mica xen... |
| 13A National highway fault | Đứt gãy đường 13A |
| Is interpreted to lie | Được lý giải nằm ở |
| Scanty (adj) | Ít, rời rạc |
| ... Are widespread | ... Rộng rãi |
| Placer occurrences | Mỏ/biểu hiện sa khoáng |
| Resource delineation | Phác hoạ/ sơ bộ xác định tài nguyên |
| Is categorized | Được phân loại |
| Within and proximal... | Bên trong và cạnh... |
| Initial economic assessment | Đánh giá kinh tế sơ bộ |
| Only been partial explored | Chỉ được thăm dò một phần |
| Greisen-style mineralization | Kiểu khoáng hoá greizen |
| Intrusive related | Thể xâm nhập liên quan với |

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