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Recent advances in exploration modelling for tin deposits and their application to the Southeast Asian environment

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Abstract: During the last decade considerable international exploration attention has been devoted to locating large tin deposits. In a general sense the programme has been unsuccessful, with very few major discoveries. However, numerous, new very large occurrences have been discovered and, perhaps more importantly, the new data base has allowed refinement of exploration models and increased perception of individual tin systems (pegmatites, porphyry tin, greisen, etc.). The importance of structural control (stockworks), alteration (argillic) and replacement controls (carbonate replacement/skarns) have been re-emphasised, and tonnage/grade perspectives refined.

It has been increasingly obvious that the utilisation of sophisticated district analysis is essential for any regional exploration program, and refinement of techniques and application are becoming critical to exploration design.

INTRODUCTION

As little as ten years ago the general consensus of market analysts predicted a good, stable, long-term future for tin. This perception attracted considerable exploration interest amongst major mining groups, and resulted in an international search for additional reserves. With the recent decline in the market strength the formerly unprecedented level of exploration activity has declined sharply.

This intense exploration activity has met with mixed success. In general terms, there has been considerable expansion of both off-shore and on-shore alluvial sources. However new, viable discoveries of hard-rock resources have been relatively few. This is particularly true of high grade reserves, although numerous marginal to subeconomic, low grade deposits have been delineated.

The new geological data has added considerably to perceptions of the characteristics of individual targets, tonnage-grade expectations, metallurgical constraints, and province expectations. It is the purpose of this paper to review and comment on the results of this recent exploration with emphasis on primary occurrences.

TARGET PERSPECTIVE

General

Target perspectives were reviewed by Taylor (1979a); and although it is difficult to acquire comprehensive information, a reasonable impression of the tonnage-grade characteristics of major tin deposits can be gained from figure 1A. It is instructive to compare this with a similar diagram compiled in 1979 (fig. 1B). The major exploration groups have concentrated on large, low grade targets (> 10 million tonnes) with the

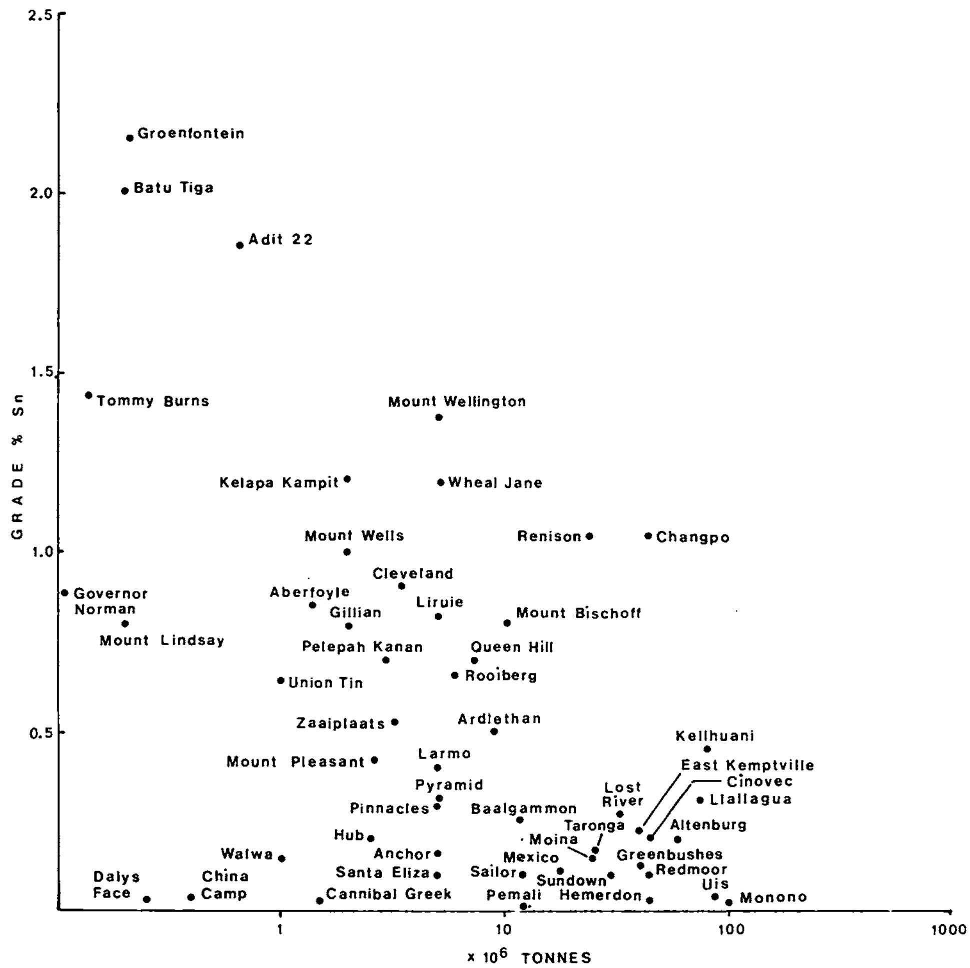

Fig. 1A. Tonnage grade diagram world tin deposits.

consequence that numerous examples in the medium to large range have been recognised. The comparison also serves to illustrate the difficulties in acquiring accurate tonnage-grade information, and it will be noted that the position of many points has been revised. For example, Hub and Catavi have been considerably reduced in size, while others such as Renison and Ardlethan have expanded in size. This problem should be recognised when inspecting the current information, and further comments are given in table 1. It can also be noted that there have been relatively few new discoveries. The majority of reserves have been generated from exploration of known tin occurrences (i.e. Taronga, Baalgammon, Liruie etc.). New discoveries include East Kemptville, Sundown and Sailor.

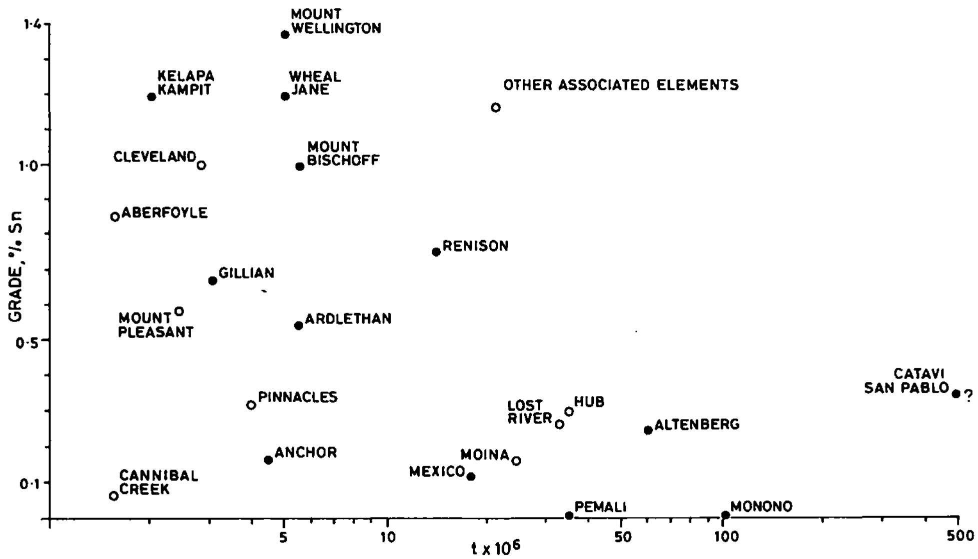

Fig. 1B. Tonnage grade diagram—deposits from Taylor, 1979a.

Systems

Target perspectives are perhaps best considered from the point of view of individual systems, and tonnage-grade data for each major type are presented in figure 2.

Within the pegmatites (fig. 2A), economic concentrations of tin are relatively rare, and the general low grades require either associated rare elements (e.g. tantalum) and/or high tonnages. Massive, greisen-style deposits (fig. 2B) seem to be characterised by relatively low grades (i.e. generally less than 0.2% Sn) and consequently require associated high grade ore, by-products (tungsten), large tonnages and/or favourable extraction economics.

High tonnage skarn deposits (fig. 2C) seem relatively rare and subeconomic, and occurrences of viable cassiterite-bearing skarns seem uncommon. Large, carbonate replacement styles, (fig. 2D) whist equally rare contain exceptional grades, and clearly, retain their position as a prime exploration target.

Brittle fracture, pipe and vein systems (fig. 2D) commonly contain moderate tonnages of high grade ore, although on an international scale the majority are small mining propositions. A rare, large tonnage example (Cinovec) is the combination of a vein/pipe system with a massive greisen system. Stockwork and sheeted vein systems (fig. 2F) are relatively common however their bulk low gradé renders the majority uneconomic. Special circumstances prevail where either weathering or primary alteration results in extreme argillisation (fig. 2G.), i.e where low cost, alluvial style mining allows extraction.

TABLE 1

TONNAGE-GRADE DATA AND MISCELLANEOUS INFORMATION

Deposit	Location	Type	Approximate Tonnage 10^6	Grade % Sn	Source	Comments
Cleveland	N.W. Tasmania Australia	Carbonate replacement	3.2	0.91		Associated Cu Underground Mine
Mt. Bischoff	N.W. Tasmania Australia	Carbonate replacement	10.3	0.80	Solomon (1965) Mining Journal (1983) Nov. p.370	Recent addition to reserves. Prospect.
Renison Bell	N.W. Tasmania Australia	Carbonate replacement	25.3	1.05		Underground mine
Batu Tiga	E. Peninsular Malaysia	Carbonate replacement	0.2	1.59–3.52	–	Pyrrhotite ore in magnetite skarn? system.
Changpo	Dachang, China	Carbonate replacement + veins	40–50	0.8–1.4	Walshe (pers. comm.)	Pyrite rich
Mt. Lindsay	N.E. Tasmania Australia	Skarn	0.2	0.8	–	Magnetite skarn. Prospect.
Pelapah Kanan	E. Peninsular Malaysia	Skarn	3.0	0.7	–	Mafic skarn? Mostly in magnetite-metallurgical problem. Partially mined open cut.
Larmo	Dachang, China	Skarn	3–5	0.4	Walshe (pers. comm.)	Associated Cu, Zn underground mine
Lost River	Alaska	Skarn	33.0	0.27	Mining Journal (1972) p. 407.	Associated W, F Prospect. Wrigglite skarn prospect.

TABLE 1 (contd.)

Deposit	Location	Type	Approximate Tonnage 10^6	Grade % Sn	Source	Comments
Moina	N.W. Tasmania Australia	Skarn	25–30	0.10	-	Associated W, F Prospect. Wrigglite skarn prospect.
Pinnacles	Queensland Australia	Skarn	3–5	0.30	-	Associated F Wrigglite skarn prospect.
Gillian	Queensland Australia	Skarn	2.0	0.80	-	Magnetite skarn prospect.
Machang Setahun	E. Peninsular Malaysia	Skarn? Replacement? Volcanogenic?	0.04	1.89	-	Old iron ore mine. Stratabound.
Mt. Pleasant	New Burnswick	Breccia pipe?	2.6	0.42	Tin Int. (1982)	With associated W, Mo, Bi Underground mine?
Mexico	Mexico	Breccia pipe?	18.0	0.10-	Ypma pers comm	Prospect-rhyolite
Hub.	Czechoslovakia	Massive? Greisen	2–3	0.2	-	With associated W, Open cut
Cinovec	Czechoslovakia	Massive? Greisen + veins	44	0.2	-	With associated W and Li Underground mine
Zaaiplaats	South Africa + pipes	Greisen + disseminated	3.2	0.53	Lenthall (1974) Ann. Rep (1983)	With associated W Open cut and underground mine
Sailor	Queensland Australia	Massive	12.0	0.10	-	Prospect
Anchor	N.E. Tasmania	Massive	5.0?	0.16	-	Open cut—now a prospect Additional reserves 1981–1982

TABLE 1 (contd.)

Deposit	Location	Type	Approximate Tonnage 10^6	Grade % Sn	Source	Comments
East Kemptville	Nova Scotia Canada	Massive + veins	40.0	0.22	Min. Mag (1983) March p. 191	Preparing to Mine
Altenberg	GDR	Massive + Stockwork	60 80?	0.20 -30?	-	
Catavi, Llallagua	Bolivia	Breccia Pipe	76.0	0.30	-	Part of major vein system. Underground mine.
Ardlethan	N.S.W. Australia	Breccia Pipe	9.0	0.50	-	Recent addition to reserves. Open cut and underground.
Greenbushes	West Australia	Pegmatite	40.3	0.125	Tin Int. (1983) p. 13	Associated niobium-tantalum
Uis	Namibia	Pegmatite	87.0	0.133	Min. Mag. (1983) p.291	Open cut
Monono	Democratic Republic, Congo	Pegmatite	100.0	0.02		Open cut. Weathered, worked as an alluvial.
Walwa	Victoria Australia	Pegmatite	1.0	0.10–0.15		Open cut. Old mine associate Ta
Adit 22	Indonesia	Vein/Stockwork replacement	0.65	1.85	-	Underground mine—open cut
Kellhuani	Bolivia	Stockwork	9.0	0.5	Lehmann and Schneider (1981)	Prospect (Old Mine)
Baalgammon	Queensland Australia	Stockwork replacement	11.5	0.25	-	Associated Cu and Ag. In porphyry dyke. Prospect

TABLE 1 (contd.)

Deposit	Location	Type	Approximate Tonnage 10^6	Grade % Sn	Source	Comments
Taronga	N.S.W. Australia	Sheeted vein	25.0	0.17	Tin Int. (1982) P. 252	Prospect
Sundown	N.S.W. Australia	Sheeted vein	30.0	0.10	-	Prospect
Pyramid	N.E. Tasmania Australia	Sheeted vein	4.0	0.315		Prospect
Redmoor	Cornwall England	Sheeted vein	44.0	0.10	Tin. Int. (1982) p. 211	Prospect. Associated Cu
Hemerdon	Cornwall England	Sheeted vein	45.0	0.025	Min. Mag. (1979) Oct. p. 342–351	Minor tin— in tungsten prospect.
Governor Norman	Queensland Australia	Stockwork Pipe & Vein	0.1	0.88	Pollard & Taylor (1983)	Open cut and underground Mine
Cannibal Creek	Queensland Australia	Sheeted vein	1.5	<0.1	-	Prospect
China Camp	Queensland Australia	Argillic + Greisen	0.4	0.03 0.05		Old mine
Daly's Face	Queensland Australia	Argillic + tourmaline vein	0.2 0.3	0.03 0.05	-	Old sluicing face
Pemali	Bangka Indonesia	Argillic Greisen	10.0?	0.01	-	Open cut
Mt. Wells	N. Territory Australia	Vein	1.0–2.0	1.00	-	Old mine

TABLE 1 (contd.)

Deposit	Location	Type	Approximate Tonnage 10^6	Grade % Sn	Source	Comments
Aberfoyle	N.E. Tasmania Australia	Vein	1.6	0.85	-	With associated W. Mined out.
Tommy Burns	N. Queensland Australia	Pipe	0.13	1.43	Pollard & Taylor (1983)	With associated W. Underground mine
Queen Hill	N.W. Tasmania Australia	Veins-Pipes	7.3	0.70	Ann. Report (1981)	From 3 ore zones
Liruie	Nigeria	Vein	5.1	0.82		Prospect?
Mt. Wellington	Cornwall, England	Vein	5.0	1.37	Mining Journal (1974) p411	Underground mine
Wheal Jane	Cornwall, England	Vein	5.0	1.20	Mining Mag. (1971) p420–429	Underground mine
Kelapa Kampit	Indonesia	Vein	2.0	1.20	Omer Cooper *et al.* (1974)	Old mine under exploration
Groenfontein	South Africa	Pipes + greisen	0.2	2.15	Lenthall (1974)	Underground mine—closed
Rooiberg	South Africa	Veins/Pipes	6.0	0.66	Lenthall (1974)	From group of orebodies—ie. several mines. Recent production added to Lenthall 1974. Underground mine.
Union Tin	South Africa	Vein	0.8	0.64	Lenthall (1974)	Underground mine.

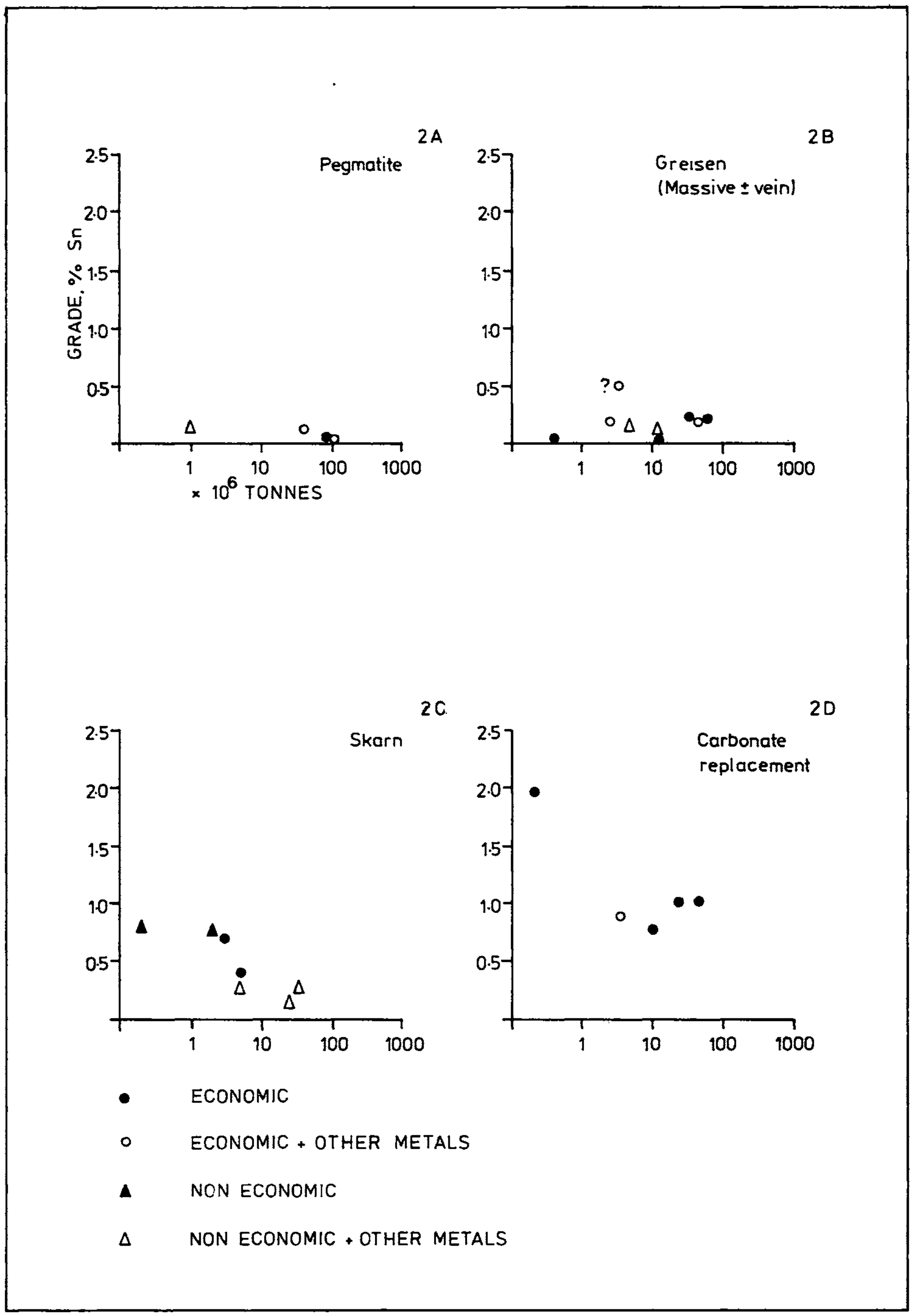

Fig. 2. Tonnage grade diagrams for individual deposit type.

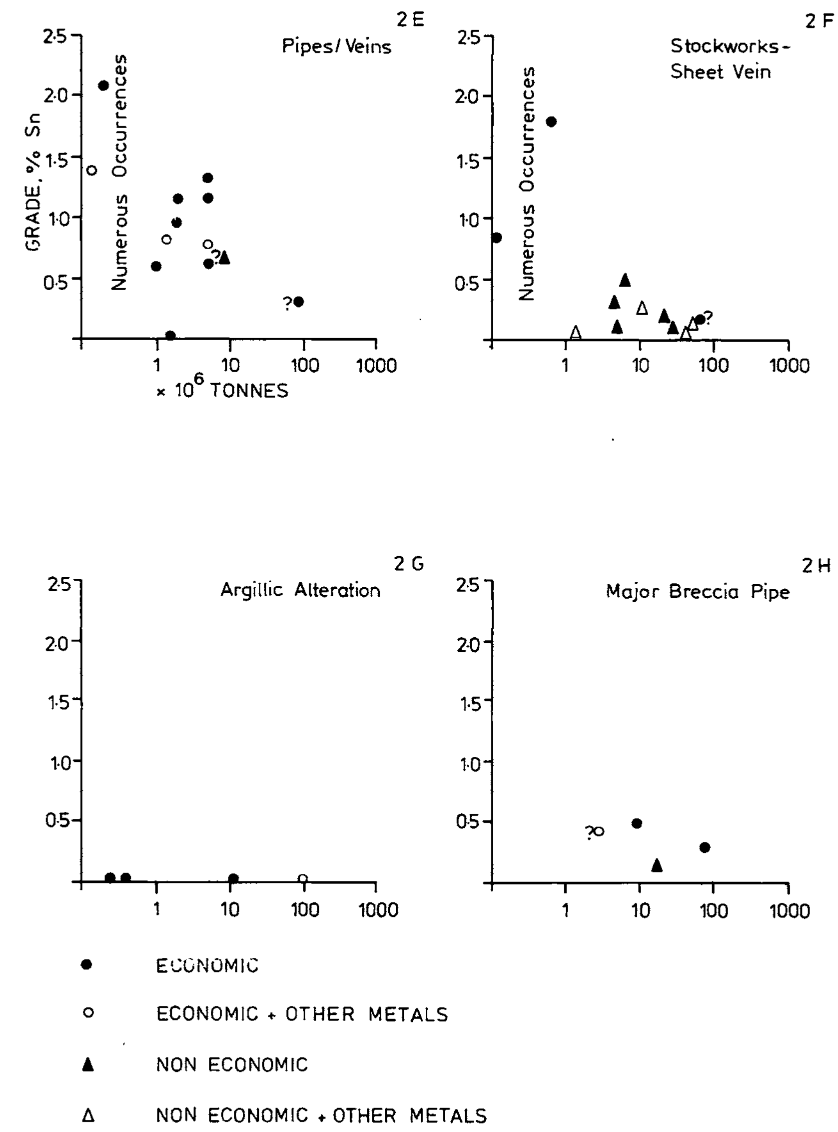

Fig. 2 (cont'd.). Tonnage grade diagrams for individual deposit type.

Major breccia pipe systems (fig. 2H) are rare and relatively low grade, although tonnages may be significant (Llallagua).

Although it is difficult to generalise on an international scale, the vein systems offer low to moderate tonnages of high grade ore. The carbonate replacement styles are extremely attractive, with both high grades and substantial tonnage. The bulk of the high tonnage, low grade styles require special mining/economic conditions or associated rare elements. Within this context, the choice of target model demands careful geographic and geological consideration.

MODELLING

The Carbonate Replacement Model (Renison Type)

From the tonnage grade perspective the carbonate replacement styles of mineralisation have naturally attracted major attention. The basic geological/exploration ingredients of this model are shown in figure 3, and include:-

1. carbonate units (carbonate-rich rocks, calcareous clastics, etc.);
2. major fault/fracture zone to focus fluid flow i.e.major fault systems;
3. tin-bearing granitoid (rich in boron $\pm$ fluorine);
4. distal position relative to mineralising granite;
5. major geophysical response from massive pyrrhotite.

Large scale exploration approaches have operated empirically by selecting appropriate carbonate-rich terrains and focusing targets via airborne geophysics, especially magnetics. This approach has successfully delineated geophysical anomalies in many regions. In the Australian environment targets have been easily generated within most tin provinces (western Tasmania, New England, Kangaroo Hills and Herberton). This approach also generated targets in lesser known,minor tinfields, and even resulted in the discovery of a major extension to the central New South Wales tin province (Doradilla). However, despite successful target generation both within Australia and in other regions follow-up exploration has failed to discover any major additional example of the replacement style. In nearly every case, the geophysical response proved to be related to various types of iron-rich skarn eg. magnetite.

This lack of success suggests that either the modelling is incorrect, or that such deposits are extremely rare. It has been suggested by Hutchinson (1979) that the Renison deposit is essentially exhalative/volcanogenic, and this has caused considerable discussion (Solomon, 1980; Patterson *et al.*, 1981; Hutchinson, 1982; Patterson, 1982). Three major examples of this type occur within western Tasmania (Renison, Cleveland and Mount Bischoff) and are the focus of current research. While much of this work remains unpublished the unanimous conclusions support the general features of the replacement model (e.g. Collins, 1981; Patterson *et al.* 1981).

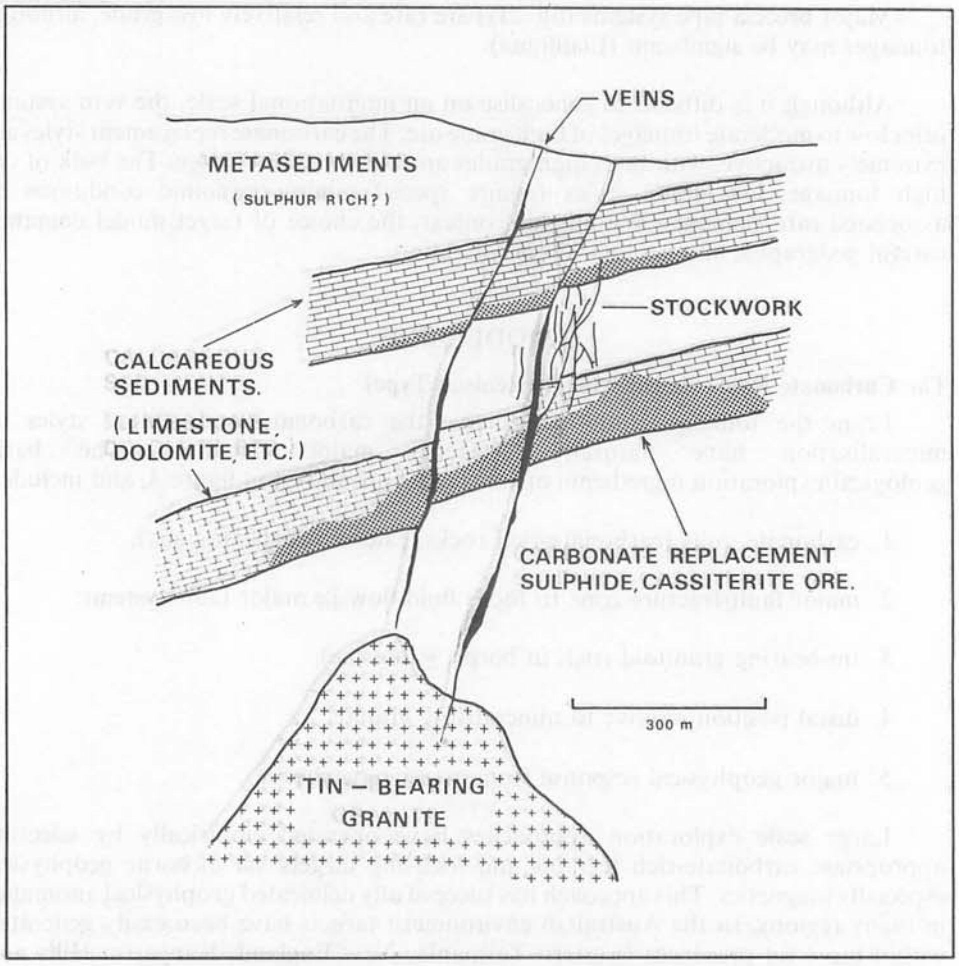

Fig. 3. Carbonate replacement model based upon Renison Bell mineralisation, north-west Tasmania, Australia (Taylor, 1979b).

The reasons for the apparently rare occurrence remain speculative. The model requires a specific combination of structural controls allowing large volumes of tin-rich solutions to interact at relatively low temperatures with favourable host rocks. Possibly these conditions are only rarely met. Alternatively, there may be additional ingredients which are poorly understood. For example, the model requires extremely large amounts of both sulphur and iron. These could be acquired either by leaching from appropriate sediments during fluid transit, or be derived from the original magmatic fluid. Possibly the structural and chemical constraints combine to produce extremely rare situations?

It is interesting to note that the Changpo example is pyrite dominated, which suggests that too-great an emphasis on magnetic approaches would risk missing orebodies.

The systems also appear to contain other metals (lead, zinc, tungsten) which offer the potential for zonal arrangements which must also be considered within the basic model (Collins, 1981).

The Greisen Model

Considerable international exploration has centred on locating large, low grade, massive greisens similar to those documented in Czechoslovakia/G.D.R. The standard model (Shcherba, 1970; Beus and Zabashkova, 1964) has proved quite successful in conceptual terms. Numerous examples of these systems have been located, including the discovery of East Kemptville within an essentially new tinfield. However, several new perspectives have emerged. Firstly, the large majority of these sytems are open systems (Tischendorf, 1973) consisting of narrow, dispersed vein-style mineralisation i.e. have been overoptimistic, and the occurrence of large, viable systems is clearly rare. Most systems, regardless of tonnage appear to be within the 0.05–0.2%Sn range (Sailor, northeast Queensland; Mt Paris, northeast Tasmania; etc).

Despite this, the target still remains attractive given the appropriate geographic/economic environments, particularly where there is an expectation of associated elements.

A component of the greisen system which has received some attention has been the early phase feldspathic alteration/mineralisation. In some regions this appears to predominate, and offer potentially large, low grade concentrations (e.g. Nigeria). Within the Australian context similar systems have been located within the Emuford-Mowbray Creek region of the Herberton tinfield. Minor occurrences have also been noted at Kangaroo Hills, Cooktown and northwest Tasmania.

In parallel with the greisen systems, massive concentrations are rare and all of the Australian occurrences are very small, fracture controlled, open systems. However the commercial occurrence at the Zaaiplaats mine in South Africa (Strauss, 1954) provides an important new conceptual variation. The Zaaiplaats occurrence (figure 4) is an

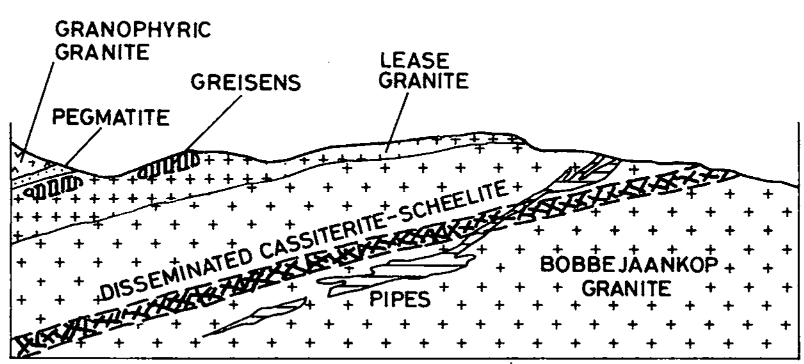

Fig. 4. Zaaiplaats Tin Mine, South Africa (modified from Strauss, 1954).

essentially closed tin-tungsten system comprising an upper zone of massive, sheet greisen within a highly altered, feldspathised granite cupola (apogranite). However there is also a lower horizon paralleling the granite contact which consists of extremely albitised granite which contains interstitial cassiterite and scheelite. This forms the bulk of current production, and is amenable to large scale extraction.

This represents an important addition to the greisen model since the potential presence of lower, mineralised horizons is rarely tested. There are obvious analogies with molybdenum systems (Mutschler *et al*, 1981). The horizons of feldspathic alteration are difficult to recognise, and careful petrological examination is required.

The Stockwork/Brittle Fracture Model

Previous tin exploration modelling had devoted little attention to the occurrence of stockwork styles. These cannot be regarded as a genetic category but nonetheless form a structural grouping with large tonnage, low grade potential. Consequently, numerous systems have been recently tested.

Although only a few examples are shown on figure 2F it is apparent that stockwork systems are very common and occur at all scales. There are numerous examples of small-scale, economic concentrations (e.g. Governor Norman, Queensland); however the larger occurrences rarely bulk at greater than 0.2% Sn and the majority are less than 0.1% Sn.

There are many variations (figure 5) upon the stockwork theme such as sheeted vein systems (Taronga, N.S.W.), brecciated, crackled systems (Kelluhani-quartzite, Baalgammon-porphyry dyke) and combinations of the above (Governor Norman). Particularly interesting situations arise where a major brittle fracture-stockwork system occurs within reactive rocks (Adit 22/Kelapa Kampit) or in combination with massive greisen systems (Altenberg).

However, in general terms the larger deposits within hard rocks require specialised conditions to become economic, e.g. associated elements, innovative mining and/or metallurgical approaches. A new technological approach via colour sorting as exemplified by the Mount Carbine (Qld) tungsten sheeted vein system requires careful evaluation for similar tin systems.

Breccia Pipe Model

The breccia pipe model as exemplified by several major Bolivian systems (Sillitoe *et al*, 1975; Grant *et al*, 1980), although attractive, seems to be a relatively rare occurrence. This possibly reflects the lack of subvolcanic tin provinces in general. An additional major system has been recognised at Ardlethan (N.S.W.) and many small occurrences of intrusive breccia pipes have been recently recorded (Allman-Ward *et al*, 1982, Goode and Taylor 1980; Wells, 1978; Pollard and Taylor, 1983; Clarke, 1979). The Ardlethan system has only minor subvolcanic affinities and the remaining new occurrences are within relatively deeper environments. This introduces the possibility of major breccia pipe systems at deeper levels but it still appears that exploration success is optimised in shallow environments.

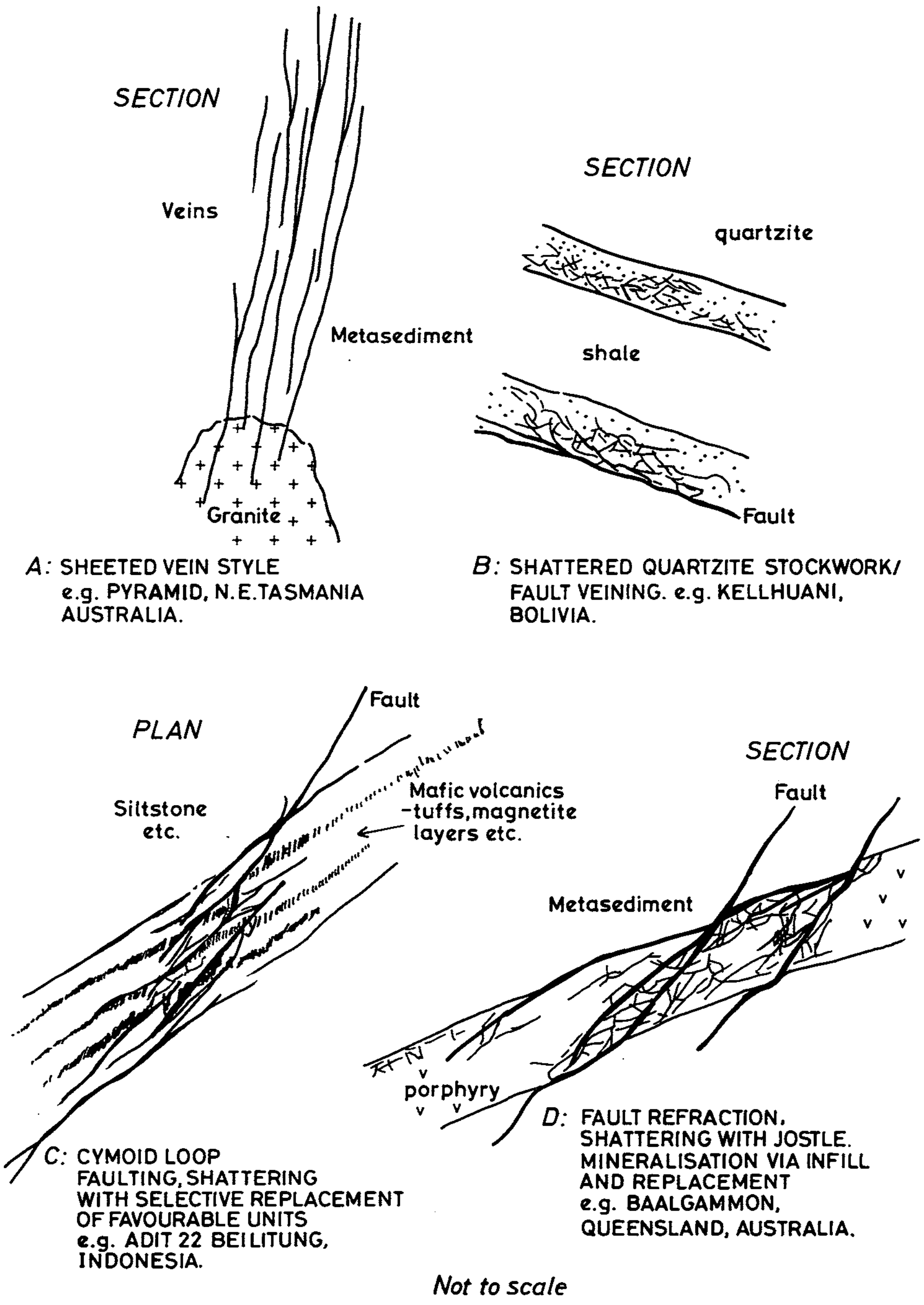

Fig. 5. Stockwork/sheet vein systems.

It should be noted that there is a close association between breccia pipe occurrence and boron-rich fluids.

Argillic Model

The argillic model has received little attention and again, cannot be regarded as a purely genetic concept. However, it is apparent that several large scale operations exist which are viable due to their soft-rock characteristic ("softies"). Such systems occur within a wide range of model types. Almost any low grade occurrence within regions of intensive, deep weathering profiles becomes a potential target. Thus Monono, and to a limited extent, Greenbushes (pegmatites), Rahman Hydraulic (stockwork) etc. have been able to conduct viable, alluvial-style operations.

Argillic alteration can also occur in many primary tin systems. It is especially well developed in association with tourmaline (boron)-rich occurrences, particularly with sheeted quartz-tourmaline veins (Bray and Spooner, 1983) and also with greisen systems (Pemali). Indeed, there appears to be a spectrum between the flourine-dominated greisen systems and the less well known boron-rich systems (Cooktown; Taylor, 1979b, Tate, 1983). Primary argillisation is enhanced by tropical/deep weathering. Many argillic-dominated systems form topographic lows, and are overlain by associated alluvium.

Other Models

The remaining major models have seen relatively few additional conceptual advances. Skarns have been demonstrated to be extremely abundant although their general small size, erratic grade distribution and metallurgical complexity has been amply confirmed. The main types include magnetitic skarns derived by interaction with either carbonate or basaltic rocks, magnesium-rich skarns derived from serpentinised mafic and calcareous rocks, and high fluorine wrigglite skarns (Kwak and Askins, 1981).

The pegmatites still form attractive targets, with new, viable occurrences being discovered (Greenbushes, W.A.; Goias district, Brazil) and reserves considerably extended within known deposits (Uis, Namibia).

Vein systems, despite difficulties in establishing ore reserves continue to provide extensions of known reserves and occasional new discoveries or reopening of former mines. In this sense they still provide attractive targets, even within high cost environments (e.g. Wheal Jane-Mount Wellington, Cornwall).

PROVINCE SELECTION—TARGET GENERATION

The above review of model systems provides a framework for target selection in general, which must be carefully considered in relation to individual provinces, and also to individual regions within provinces. It is emphasised that certain styles of deposits are favoured within specific geological environments. Hence the identification of province type (Taylor, 1979b) is critical. For instance, massive greisens are favoured in quiet, plutonic domains, breccia pipes within subvolcanic terrains etc.

An important initial process both in province selection and target selection is detailed district analysis. District analysis becomes particularly important when the nature of the province is uncertain, when exploration activity has generated new information, and for application of model type target selection.

Numerous approaches are available and the selection and application of techniques is controlled by the aims of the investigation. Techniques which find wide application include the following.

1. Generation of a map showing location of all mineralised occurrences. This is an essential step which frequently requires considerable literature and map search, and compilation at an appropriate scale. During this phase the primary data base of published and unpublished material is assembled for later consideration.

2. Economic perspectives. Utilising the distribution map and data bank, the following can be considered for establishing both target perspectives and preliminary exploration potential—

   a. tonnage-grade diagrams (regional, and local). (Pollard and Taylor, 1983)

   b. production distribution map

   c. intensity of mineralisation map (contouring).

3. Geological perspectives can be gained by considering—

   a. distribution of selected rock types e.g. granites, carbonates etc. This includes an understanding of the topography of the upper surface of granitoid intrusions.

   b. metals distribution maps

   c. selected mineral distribution maps (e.g. stannite versus cassiterite)

   d. lineaments, faults etc.

   e. geophysical maps

   f. geochemical maps.

   g. granitoid maps (e.g. type of granite S,I,A, etc., and where possible relevant geochemical data).

4. Deposit types
   Preparation of deposit type maps is extremely difficult and requires careful and expert consideration. It is essential to clearly develop classifications: these can be simple (e.g. primary versus secondary), structural (e.g. veins, stockworks, massive etc.), or genetic (skarn, replacement, etc.). Genetic classifications are especially difficult and may be assisted by field inspection. Frequently the genetic type will be uncertain. Types of plots for consideration include—

a. secondary concentrations

b. types of secondary concentrations (e.g. piedmont, stream, etc.)

c. primary deposits

d. structural types

e. genetic types

f. mineralogical types—ore constituents

g. mineralogical types—alteration styles/minerals

5. Application of models.

a. Secondary accumulations—prime considerations here include geomorphic history (recent and palaeo drainage reconstruction) involving plotting river systems, all known alluvium, relevant topography, basalt flow systems, faults etc. Special attention should be paid to primary deposits lacking known alluvials.

b. Primary accumulations—this involves isolating both primary and secondary ingredients of known models and relating them to the accumulated data base. Regions/deposits can then be classified according to the number and/or importance of contained characteristics. For instance, in developing a carbonate replacement classification, major weighting would be given to carbonate, presence of pyrrhotite etc. whilst minor weighting would be given to lead-zinc occurrences. Similarly, in greisen exploration major attention would be focussed upon developing a classification for detecting shallow, concealed cusps in known greisen-bearing districts, e.g. fracture patterns, contact metamorphism, leakage (minor vein mineralisation), porphyry dykes etc.

DISTRICT ANALYSIS WITHIN THE MALAYSIAN ENVIRONMENT

Until comparatively recent times relatively little was known concerning the primary tin deposits of Malaysia. The dominance of alluvial production and the apparent lack of major hard rock occurrences naturally directed geological attention towards the secondary environment.

Within the last twenty years, concepts and understanding of factors controlling mineralisation types have advanced considerably, particularly with respect to evaluation of environment potential and comprehension of tin systems. New models have emerged concerning deposit types, e.g. carbonate replacement, intrusive breccia pipes etc., and older models have been dramatically advanced with respect to their position within individual systems, and their application to exploration.

The pioneering work by the various surveys, universities and individual authors has recorded and collated some of the details of the primary mineralisation in

Malaysia. Although the data bank is still at a preliminary stage, the situation is well placed for district analysis. It can be noted that potential for greisen systems, carbonate replacements, stockworks/sheeted veins and argillised ('softies') situations is high, and delineation of favourable zones is well justified. For instance, the eastern tinfields contain abundant occurrences of magnetite (high iron environments), carbonate rocks, and documented occurrences of stanniferous pyrrhotite. Numerous deposits of apparently uncertain origin are recorded (e.g. Machang Setahun), together with widespread alluvials which have uncertain primary sources. District analysis is amply justified at both the regional and local level to establish the required data base for the direct application of the carbonate replacement model.

Despite the recent studies, very little is known concerning province type or details of individual districts throughout Malaysia. The western and eastern provinces are correctly regarded as deep—subvolcanic in character (category 2 of Taylor 1979b) (Yeap, 1979), and as such offer a wide range of potential (fig. 6). Yeap (1979) considers that the differing mineralisation styles within the two provinces is a function of the environment into which the granitoids have been emplaced. Within the Kuala Lumpur region he recognises two ages of mineralisation with quite different characteristics, and

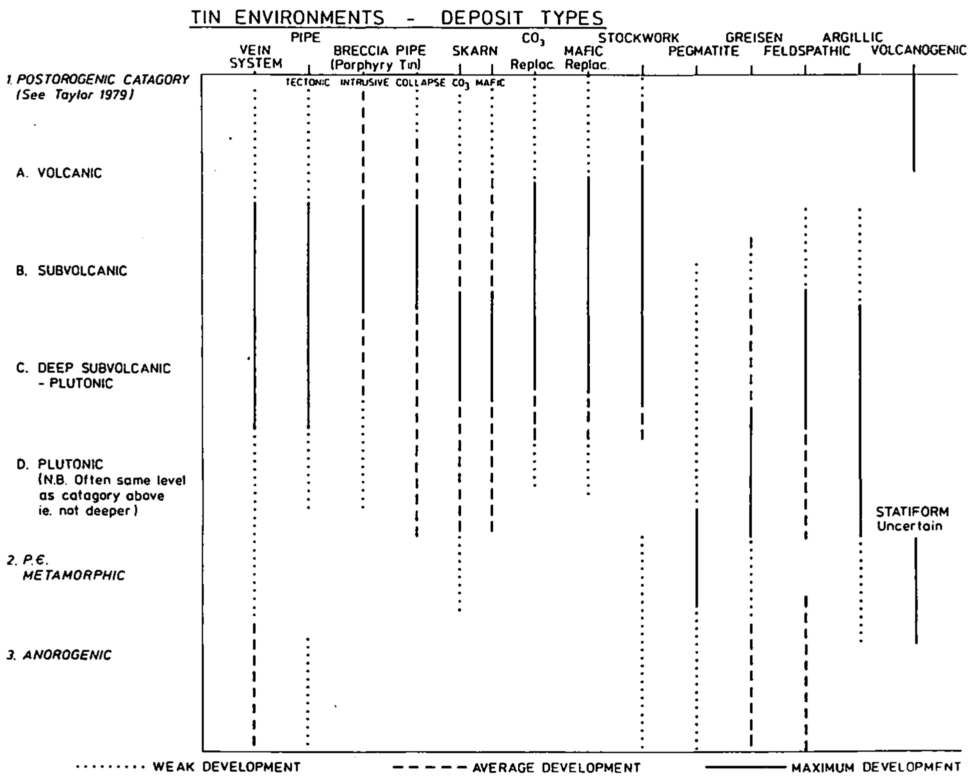

Fig. 6. Deposit type development in relation to province type.

hence different exploration potential. It is probable that international experience will be repeated in Malaysia, with each individual tinfield containing well-defined and distinctive characteristics. Several tinfields contain sufficient accumulated data to allow categorisation via district analysis, and this perspective would provide an invaluable broad and local scale insight for establishing exploration priorities and target selection. As alluvial sources decline, the established data bank will become of increasing importance for primary deposit exploration.

Within the remaining Southeast Asian tin provinces there has been a similar recent accumulation of geological/exploration data, and each region deserves close consideration for the application of detailed district analysis.

ACKNOWLEDGEMENTS

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