Geotectonics and Metallogeny of SE Asia and Myanmar

Opportunities for Exploration and Discovery

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Introduction

Review of Myanmar and SE Asia geotectonics and metallogeny based on:
• more than 12 years experience in the country;
• nearly 20 years experience in mainland SE Asia;
• regional and district scale metallogenic understanding

CSA Global
• International mining industry consultancy with offices in Perth, Brisbane, Jakarta, London, Johannesburg, and Vancouver;
• Provides geological and engineering services across the industry spectrum from regional exploration to feasibility and mining;
• Specialist expertise in SE Asia with extensive project experience in all the ASEAN countries.
Geology and Mining - Background

- Historical production of gold, silver, jade and gems
- Development of a colonial mining industry under British rule
- Bawdwin Mine and Nam Tu smelter was the biggest mining complex; Sn-W in Tennasserim also important
- Main focus was on oil; most of the country remained unmapped and unexplored
- Post-war and post-independence decline and 1963 nationalisation
- Limited exploration, mines developed at Monywa and Kyaukpahto, both with Yugoslav assistance
- Ongoing decline in production of Zn, Pb, Cu, Sn & W from colonial levels
Geology and Mining - Background

- 1987-88 upheaval and political change
- 1994 Mining Law and mid-90’s tender block rounds led to the first modern exploration in Myanmar, though limited in scope and extent
- Newmont – short-lived exploration at Kyaukpahto and Sagaing block
- Ivanhoe/Indochina Goldfields/First Dynasty; Monywa, Wuntho massif, Slate Belt
- Mandalay Mining exploration around Bawdwin
- Also Mindoro, PacArc, Palmer Resources, Leeward, International Panorama, etc.
- No new discoveries; Monywa redeveloped
- 1997-1998 global exploration industry collapse and prolonged subsequent downturn
- No exploration during the 2004-2011 boom; Asian investment in existing projects
- Myanmar missed the boom(s) and remains almost entirely unexplored
• SE Asia – Eastern Tethyan belt
• Myanmar occupies a complex geological boundary zone between the present-day Asian and Indian plates
• Active subduction zone/volcanic arc until the Mid-Miocene (c. 13 Ma), now a transform boundary along the crustal scale Sagaing Fault
• Approximates the older boundary between the Sibumasu Terrane and the West Burma Terrane, partly offset and oroclinally folded by more than 800 km dextral offset on the Sagaing Fault.
Myanmar Metallotects

Basis for subdivision of the country into 10 metallotects:

1. Rakhine accretionary prism
2. Indo-Burman Ranges ophiolitic thrust belt
3. Central Myanmar sedimentary basins (western and eastern)
4. Central Myanmar volcanic arc
5. Kachin ophiolite/arc complex
6. Mogok metamorphic belt
7. Slate belt
8. Shan-Thai block (Shan Plateau)
9. Doi Inthanon – Changning-Menglian belt
10. Sukothai volcanic arc/fold belt

Geological Map of the Union of Myanmar, DGSE, 2008
Metallogeny and Potential

- Understanding of mineralisation and mineral potential of Myanmar is directly related to understanding of tectonic evolution and related metallogeny.
- Deposit preservation related to uplift and erosion is also of critical importance especially for epithermal Au and porphyry Cu systems.
- Despite limited past exploration in Myanmar, knowledge from surrounding region can be used to prioritise potential and opportunities.
- For metallic minerals, significant deposits of Cu, Au, Zn-Pb-Ag, and Sn-W exist within the country or in metallogenic belts that run into the country.
Cambro-Ordovician

- Active northern Gondwana plate margin or Serindian convergence?
- Bawdwin volcanic centre; Early Ordovician(?) rhyodacitic tuffs and flow-dome complex, overlying Cambrian flysch
- 1938 Bawdwin reserve 10.8 Mt at 22.8% Pb, 13.9% Zn, 1.05% Cu and 670 g/t Ag
- 1990’s Indicated and Inferred ‘halo’ resource 104 Mt at 5.6% Pb, 2.3% Zn, 0.2% Cu, 71 g/t Ag
- Structurally controlled and cross-cutting lodes – feeder system or late remobilisation?
- Potential outside the Bawdwin volcanic centre; Longtawkno-Kyaukme and Moho Chaung
- Unrecognised volcanic centres?
- Vein-hosted deposits in Precambrian and Cambrian clastics; Yadanattheingyi

From Metcalfe http://metcalfeian.com/web-data/Research/PalGeog/Palaeogeog.html

Modified after Carpenter, 1964
Lower Ordovician Irish-type Zn-Pb-Ag-Ba

- Carbonate-hosted Pb-Zn-Ag-Ba deposits in extensive Lower Ordovician platform sequences over 1000 km of strike from Kanchanaburi to western Yunnan
- Stratabound disseminated to semi-massive sulphide in shallow water clean limestone overlying marginal marine carbonates and clastics
- High Ag, low Fe sphalerite, elevated Sb, As, Hg
- Moderately to strongly deformed and metamorphosed in Silurian?
- Conformable Pb isotopes, similar to Bawdwin
- Zircon U/Pb of tuff horizons in carbonates c. 464 Ma – similar age to Bawdwin?
- Carbonate-hosted Pb-Zn-Ag deposits “Irish-type” in back-arc setting?
- Correlation with Canning Basin?? Admiral Bay – 72 Mt at 3.1% Zn, 2.9% Pb, 18g/t Ag and 11% Ba
Lower Ordovician Irish-type Zn-Pb-Ag-Ba

- Kanchanaburi global resources >8 Mt at c. 7% Pb, 3% Zn and 100g/t Ag; Zn-rich (Bo Yai; c. 7.5% Zn) and Pb-rich (Song Tho, Bo Ngam) deposits
- Li district – extensive stratabound Zn-Pb-Ag-Ba mineralisation in impure limestone; associated silica-dolomite alteration / diopsidic calc-silicate
- Phu Mai Thong (>7 Mt barite); massive bedded barite in carbonaceous shale-siltstone above main sulphide horizons
- Mae Chong; stratabound horizons of disseminated to semi-massive Zn-Pb-Ag mineralisation over 7.5 x 1.8 km area - grades up to 13% Zn, 2% Pb and 40 g/t Ag close to feeder zones
- Bawsaing District; extensive small lead and barite deposits associated with folded banded sphalerite and oxidised zinc; no systematic modern exploration
- Shan State; Lufang?, Long Keng?
- Yunnan; Menxing, Dongshan

Folded banded sphalerite, Mae Chong
Bedding-parallel barite ore, Phu Mai Thong mine
Song Tho galena-rich replacement ore

Mengxing
Carboniferous SHMS in Sibumasu

- Carboniferous extension and incipient rifting in NE Gondwana
- Deepening sequences overlying Visean platform carbonates
- Late Carboniferous to Late Permian rift and drift of Cimmeria/Sibumasu
  Rift-related basinal deposits; SHMS in Sibumasu and Indochina
- Sopokomil SHMS, Sumatra; 24.3 Mt at 10.3% Zn, 6.0% Pb, and 8.3 g/t Ag (Measured, Indicated and Inferred)
- Stratabound massive sulphide over 4 km in carbonaceous dolomitic shale/siltstone unit on NE side of Sopomomil Dome
- Trangressive deepening sequence; hangingwall calci-turbidites
- Correlative sequences in Myanmar?
- NW Australia Late Devonian and Early Carboniferous MVT’ districts

From Stampfli and Borel, http://www.unil.ch/igp/page76652.html
Carboniferous to Triassic VHMS

- Active Indochina/Simao margin and peripheral rifted arc terranes; Loei, Sukhothai and Changning-Menglian belts
- Gold-rich polymetallic VHMS in back-arc settings:
  - Sukhothai VHMS; e.g. Dapingzhang (c. 63 Mt at 0.8% Cu), Nam Rin (Ba-Au + Zn), Tasek Chini (Malaysia Ba-Cu-Zn-Au)
  - Changning-Menglian belt

Massive pyrite and barite, Nam Rin

From Stampfli and Borel, [http://www.unil.ch/igp/page76652.html](http://www.unil.ch/igp/page76652.html)
Gold and Copper in Permo-Triassic Arcs

- Permo-Triassic arc volcanism on the Indochina/Simao margin – Loei and Sukothai to Changning-Menglian belts
- Epithermal and porphyry deposits in the Loei-Phetchabun-Pak Lay belt

From Stampfli and Borel, http://www.unil.ch/igp/page76652.html
Triassic Indosinian Orogeny

- Late Triassic to Jurassic culmination of Indosinian orogeny; collision of Sibumasu with Indochina/South China
- “Slate Belt” orogenic gold, e.g. Modi Taung, Russell Island etc.; high grade, low tonnage
- Triassic MVT? deposit c. 0.2 Mt
- Late Triassic late-orogenic granites; Central Belt granites; Sn-W mineralisation, western Malaysia
- Late Triassic – subduction initiates on the western Sibumasu margin; Lemyethna Cu-Au VHMS in fore-arc
- Jurassic – Sibumasu and South China active margins
- Late Jurassic incipient Gondwana rifting

From Stampfli and Borel, http://www.unil.ch/igp/page76652.html

Modi Taung gold deposit
Long Keng Zn-oxide deposit
Cretaceous Lhasa/West Burma Orogen

- Cretaceous subduction and collision of the Lhasa – West Burma – Woyla terranes/arcs
- Deformation in the Central Myanmar Arc
  - Orogenic gold, Kyaukpazat, Legyin etc. – extensive narrow-vein gold systems; high grade, low tonnage
- Late Cretaceous A-type tin granites on Andean-type margin
  - Tin granites in Sibumasu
- Cretaceous MVT
  - Padaeng, Long Keng?

Cretaceous Orogenic Gold

- Exemplified by gold systems in the Wuntho Massif of the Central Myanmar Arc
- Many small deposits along the Legyin Fault; back-arc transform with reverse movement during compressional deformation event
- Shear/vein hosted mesothermal gold within andesitic flows and tuffs
- Pyrite with associated Zn-Pb-Cu sulphides and minor arsenopyrite
- Chlorite to quartz-sericite and carbonate alteration
- Typically individual narrow veins; potential for sheeted veins in structurally favourable settings?
- Source for extensive geochemical anomalism in gold and base metals
- Supports extensive artisanal mining
2800 km long belt from eastern Myanmar through peninsular Thailand and Malaysia to the Indonesian “Tin Islands” of Bangka and Belitung

Total estimated production c. 9.6 Mt of tin, or 54% of the world's tin production

Mainly related to two evolved granite belts:

- Central or Main Range belt in western peninsular Malaysia, southern peninsular Thailand; Late Triassic age S-type biotite granites resulting from crustal thickening following Indosinian collision.
- Western belt in northern peninsular Thailand, western Thailand and Myanmar; Late Cretaceous I-type/A-type granites in an extensional Andean-type continental back-arc setting following West Burma arc collision

Note naming convention in Myanmar has Western Belt as the Central Belt

Cretaceous province continues to Pacific margin of SE Asia and S China
Cretaceous Sn-W

- Most Sn-W in Myanmar is from Late Cretaceous Western Province granite-related mineralisation in Tanintharyi
- Most Sn production from Mio-Pliocene alluvial and eluvial palaeo-placers, e.g. Heinda and offshore dredging
- Lesser production from modern placers
- Relatively minor primary production from Sn-W greisen and vein deposits, e.g. Hermingyi
- Tungsten-rich deposits on the eastern side of the belt; e.g. Mawchi, Mae Lama
- Unrealised primary potential – greisen and skarn?
Cretaceous Zn-Pb MVT

- **Padaeng** (Mae Sod) supergene oxide Zn deposit (hemimorphite) c. 1.8 Mt cont. Zn, no Pb, no sulphide
- Mineralisation close to major NW-trending fault zone
- Small Pha De Zn-Pb sulphide deposits stratabound in ferroan-dolomitised oolitic limestone
- Replacement, breccia and cavity-fill low-Fe sphalerite, galena and pyrite
- Jurassic shallow-water carbonates peripheral to clastic basin; narrow belt extends NW into Myanmar
- Mawkhi Zn-oxide (willemite) deposit hosted in Triassic dolostone in same belt
- Long Keng – 0.4 Mt at 35% Zn as smithsonite hosted by Triassic dolostone in central Shan State
Geotectonic Evolution

Hall (2012) animation from Late Jurassic to Recent available at [http://dx.doi.org/10.1016/j.tecto.2012.04.021](http://dx.doi.org/10.1016/j.tecto.2012.04.021)
Palaeogene Arc

- Palaeogene oblique subduction with discrete sub-aerial volcanic centres along the Central Myanmar Arc
  - Monywa high-sulphidation epithermal copper deposit (early Miocene); c. 1.88 Bt at 0.37% Cu, Letpadaung, Sabelaung, and Kysintaung deposits
  - Fluidised epithermal breccia, Legyin district
Myanmar – Neotectonics

- Movement on subduction zone is oblique; no current subduction
- Most movement is taken up on Sagaing fault system and subsidiary faults

From Kundu and Gahalaut, 2012
Neogene Transform Margin

- Neogene extensional magmatism along the Sagaing Fault zone
  - Epithermal and sediment-hosted gold e.g. Kyaukpahto (>6Mt at 3g/t), Gegalaw, etc.

- Neogene transcurrent faulting and magmatism in the Mogok Belt
  - Mesothermal gold, IRG/skarn? – Kwinthonze, Tayetkhone, etc.
  - Minor skarn copper-polymetallic mineralisation
  - Epithermal potential – Tengchong-type volcanic centres

Kyaukpahto stockwork veined argillic altered sandstone

Kyaukpahto fluidised breccia and chalcedonic silification

Gegalaw palaeo-karst in Triassic limestone

Gegalaw silicified gold-mineralised karst breccia
Ni Laterite & Chromite

- Extensive ophiolite belts related to Indian collision event; mostly steeply dipping and dismembered ultramafics
  - Tagaung Taung lateritic nickel deposit; c. 40 Mt at 2% Ni
  - Mwetaung lateritic nickel deposit; c. 36 Mt at 1.5% Ni
  - Relatively small and moderate grade deposits, mainly saprolite; high capital and power costs
- Widespread small chromite deposits and occurrences
- PGM’s recorded at Indawgyi
- Jadeite at Hpakant has provided one of Myanmar’s most valuable mineral exports
Bulk Commodities

Iron-ore
- No large deposits currently known
- Potential for skarn magnetite exists in arc belts and associated with tin skarns
- Enigmatic Pang Phet deposit with reported associated Cu and U; basement or Triassic hosted?

Manganese
- Eastern Shan state; volcanic or skarn-related?

Bauxite
- No significant reported occurrences

Coal
- Extensive low-grade sub-bituminous coal in western basin, Kalewa etc.
- Small brown-coal deposits in fault basins on Shan plateau, e.g. Tigyit, Namma
Operating Framework

- Common Law System
- All minerals vested in the state; royalties are not fixed (precious metals 4-5%, base metals and ferrous metals 3-4%, negotiable)
- 1994 Mining Law set the framework for individual contracts which previously included:
  - DGSE technical support at the exploration stage
  - Principal terms and conditions of production JV with one of the Mining Enterprises – equity participation with cost recovery
  - Prospecting, exploration and production periods (total up to 10 years) with expenditure commitments and progressive relinquishment
  - Current insistence on Production Sharing Contracts and high level of ‘Signature bonus’ and ‘dead rent’ are a major disincentive to risk investment in exploration
  - Local support or participation important, or essential in ethnic areas
  - How foreign JV’s with non-state companies will be accommodated within the system is not clear
  - New Investment Law sets framework for foreign investment; approval through Myanmar Investment Commission
  - New Mining Law – when and what??
  - Will new foreign licences be issued under the current law??
Data & Services

- Improved UTM topographic map coverage at 1:50,000 from modern aerial photography
- Satellite imagery
- Geological mapping limited in extent and quality
- No useful exploration data such as geochemical datasets or airborne geophysics
- Limited technical professional experience especially in younger generation
- Low level in-country exploration services, drilling and geophysics
- Services and equipment can be imported
- Local services will quickly improve if foreign investment in exploration picks up

Geosan LLC Mongolian geophysicists with CMC team, Sagaing Project, 2005
Logistics

- Poor infrastructure, but reversal of long-term decline has begun, and challenges can be overcome
- Unreliable power supply, but substantial energy resources and improving supply
- Difficult communications, but improving rapidly especially mobile coverage and internet access
- Security restrictions are much reduced, but still an issue in some areas
Concluding Remarks

- Myanmar is part of the geologically complex SE Asia tectonic collage and encompasses a number of significant metallogenic belts from Cambrian to Neogene age with significant potential for commodities including Cu, Au, Zn-Pb-Ag, and Sn-W.
- Although a significant mining industry existed under British colonial rule, most of the country is effectively unexplored and untouched by modern exploration techniques.
- Although geological data and knowledge for many parts of Myanmar are very limited, sufficient regional understanding of geology and tectonics can guide prioritisation of target belts and optimise exploration approaches.
- Myanmar has the geological potential to develop a significant mining industry, but this requires foreign investment to make up the exploration deficit and lead to new discoveries.
- Foreign investment in exploration will only occur if a framework is instated that encourages risk investment; an investment regime that encourages risk combined with appropriate social/environmental constraints will attract serious exploration and mining companies.
- International companies following industry-standard best practice with a ‘social licence to operate’ can spearhead the development of an industry that will contribute to the socio-economic development of Myanmar.
- Partnering with local companies and use of local Myanmar service companies will help build a local responsible mining industry.