Sedimentary-Type Stratiform Ore Deposits

Wolfgang Krebs
Institut für Geologie und Paläontologie
Technische Universität Braunschweig
3300 Braunschweig, Pockelsstraße 4
DBR

Morganti (1981) described the sedimentary-type stratiform deposits and proposed a three-fold classification based on the type of sedimentary basin of deposition for the associated sediments:

1) Intracratonic basin sulphide deposits in shallow water shales, silt- and sandstones. Examples of ore deposits are those of the Central European Kupferschiefer, Zambian Copperbelt, White Pine in Michigan, McArthur River, Mt. Isa and Hilton in Australia and Largentière in France.

2) Flysch basin sulphide and barite deposits in turbidites and associated lithologies such as graywackes, siltstones, conglomerates and mudrocks. The flysch basin deposits include the stratiform, massive sulphide deposits of Rammelsberg and Meggen in Germany, and Sullivan, Tom and Jason in Western Canada. According to Morganti, these deposits are characterized by the following: a) presence of bedded barite, b) alteration-feeder zone underlying or adjacent to the deposits, and c) occurrence in sub-basins related to synsedimentary graben structures.

3) Platform-marginal basin sulphide deposits in carbonaceous laminites associated with deeper water mudrocks and cherts, outboard of cratons or platforms. The only examples of this type are the XY, ANNIV or OP deposits in the Howards Pass area, Selwyn Basin.

Considering the tectonic setting and style of mineralization, the lead-zinc-copper deposits grouped by Morganti (1981) in his intracratonic basin sulphide class are here suggested to belong to several quite different sedimentary environments. In particular, there are significant differences in the tectono-sedimentary framework between the Kupferschiefer-type (Central Europe, Zambian copperbelt) and the massive stratiform lead-zinc deposits (McArthur River, Mount Isa, Hilton).

The Central European Kupferschiefer is a stratabound, Cu-Pn-Zn mineralization of transgressive black shales as well as the directly underlying clastics ("sand ore") and overlying carbonates. The mineralized platform sediments belong to a post-orogenic, molasse-type environment (Jung and Knitzschke, 1976). The Kupferschiefer-type mineralization is not massive but disseminated, generally low grade (<2%) and persistent over a very wide area (Mansfeld, Germany -140 km^2; Subsudetian Syncline, Poland -157 km^2).

The lead-zinc mineralization of McArthur River, Mount Isa and Hilton, on the other hand, is stratiform, more massive and is areally restricted to lens-like, tabular bodies in special third-order depressions (Lambert, 1976; Large, 1980a, 1981). The Pb-Zn mineralization is high grade (McArthur River 13.5%, Mount Isa 13.2% and Hilton 17.3%) and is associated with a copper rich, epigenetic, cross-cutting mineralization. The Australian deposits were originally formed in an intracratonic pre-orogenic regime. Ores and host-sediments were affected later by stronger deformation (Mount Isa and Hilton). Only the McArthur River deposit was not deformed severely (Lambert, 1976, Large, 1981).

From a genetic point of view, the massive sulphide deposits of McArthur River, Mount Isa and Hilton were formed as conformable layers at the sediment/sea water interface (stratiform) from metalliferous exhalations (syngenetic). The disseminated Kupferschiefer mineralizations, however, are confined to a widespread, marine black shale horizon, as well as to the directly underlying clastics and overlying carbonates, and are thus stratabound. The Kupferschiefer type of mineralization is considered to be early diagenetic in origin, but in Central Europe there are many observations that significant remobilization and migration of the original metal distribution took place at a later stage (Beyschlag, 1920; Gunzert, 1953).

The sandstone-hosted Largentière deposit in France (Fogliérini *et al.*, 1980) is related to post-orogenic sandstones and arkoses unconformably resting in an older basement. The disseminated lead mineralization is epigenitic and controlled by the porosity and permeability of the transgressive clastics, "sandwiched" between the impermeable basement and sealing shales or marls (Krebs, 1981b). Richer ores are related to faults.

The sandstone-hosted lead deposits of Laisvall and Vassbo (Sweden), Maubach and Mechernich (Germany), Yava (Nova Scotia) and others (Bjørlykke and Sangster, 1981) belong to the same type.

Table I shows the very heterogeneous nature of the intracratonic basin deposits classified by Morganti (1981) and the proposed nomenclature by the present author. It is suggested that a subdivision of massive, stratiform lead-zinc deposits into two groups, as proposed by Morganti (1981), is not practicable. The similarities between massive sulphide deposits in flysch basins and the platform-marginal basins are much greater than their differences. In Morganti's terms Tom and Jason could also be classified as platform-marginal deposits (D. Large, written commun., 1981). Finally, the host sequences to Meggen, Rammelsberg, Tom, Jason and Howards Pass would be better described as pre-flysch (Aubouin, 1965, p. 83-84).

The following summary lists the characteristics of the newly defined platform-marginal deposits according to Morganti (1981) followed by the comments of the present author:

a) Simple sulphide mineralogy.
The Meggen deposit (flysch basin type of Morganti) has also a simple sulphide composition (pyrite, marcasite, sphalerite, minor galena; Krebs, 1981a).

b) Low pyrite content of the ore.
Other massive, stratiform ore deposits also contain a low pyrite content such as Tom and Jason (Carne, 1979; Large, 1980b).

c) Low Ba content and no barite deposits directly associated with the sulphide bodies.
Some sulphide deposits of the flysch basin type also do not contain barite (e.g., Sullivan). The low Ba content of the Howards Pass deposit is obviously the result of highly reducing conditions during the submarine discharge of metal- and barium-bearing brine (Badham, 1981), the content of organic carbon in the adjacent black shales comes up to 14% (R. W. Macqueen, oral commun., 1981). Interestingly, in the hanging wall sequence of the Howards Pass deposit there are widespread stratiform barite horizons developed (Morganti, oral commun., 1976).

d) Low Cu and Ag contents.
Meggen and Sullivan also have a very low copper content. The average silver content of the Meggen ore is only 3 ppm (Krebs, 1981a).

e) Association with anomalously thick sedimentary sequences.
Large (1980a, 1981) has shown that all massive, stratiform lead-zinc deposits are restricted to locally developed third-order depressions on the sea floor. The McArthur River deposit, for instance, is restricted to the HYC sub-basin in which the host HYC Pyritic Shale member attains a thickness of 530 m. The Tom and Jason deposits at Macmillan Pass are related to sediment-filled, fault-bounded, synsedimentary graben structures with higher sedimentary thicknesses (Smith, 1978; Lydon *et al.*, 1979).

f) Lack of associated feeder zones.
At Meggen an epigenetically mineralization feeder zone is only weakly developed (Ehrenberg *et al.*, 1954; Krebs, 1981a). There is no feeder zone under the Main Zone at Jason (R. Bailes, oral commun., 1981). Finlow-Bates and Large (1978) have shown that the hydrostatic pressure (water depth) at the discharge site will determine whether the precipitation of sulphides occurs in the exhalative vent prior to discharge (cross-cutting mineralization) or as bedded ore at the sediment/sea water interface (stratiform mineralization). Deposits in a deeper water environment tend to have the base metal sulphides represented in the stratiform facies (e.g., Rammelsberg, Howards Pass), whereas deposits in shallower water have large proportions of epigenetic, cross-cutting mineralization (e.g., Tynagh, Silvermines).

g) Palaeogeographic position seaward of major platform or shelves.
From a palaeogeographical point of view, the Meggen deposit has an identical position in the basin or at the slope near the Middle Devonian shelf margin (Krebs, 1981a) as Howards Pass.

In conclusion, the cited lead-zinc deposits of Meggen, Rammelsberg, McArthur River, Mount Isa, Hilton, Sullivan, Howards Pass, Tom and Jason are all considered to belong to one uniform group of massive stratiform sulphides which is geologically quite distinct from the Kupferschiefer-type mineralization as well as from the sandstone-hosted lead deposits (Table I).

The massive, stratiform lead-zinc-barite deposits can be genetically interpreted as submarine exhalative deposits, precipitated at the sediment/sea water interface from hydrothermal solutions which discharged into the sea. The channelways or feeder zones of the ascending solutions are characterized by an epigenetic cross-cutting mineralization and host-rock alteration. The deposits in question are hosted by non-volcanic marine sediments (black shales, cherts, siltstones and sandstones, conglomerates, limestones, dolomites). They were formed in a pre-orogenic regime that was characterized by synsedimentary block faulting. During later orogenic movements most of the sulphide deposits underwent intensive deformation such as folding, shearing, thrusting and cleavage. Detailed descriptions of the massive, stratiform, sediment-hosted lead-zinc-barite deposits are recently published by Large (1980a, 1981), Klau and Large (1980), and Finlow-Bates (1980).

According to the sulphide-barite relationship, the massive, stratiform lead-zinc-barite deposits can be subdivided into three groups:

1) Howards Pass type - stratiform, massive sulphides without directly associated bedded or nodular barite. Cross-cutting mineralization of the footwall sediments may be present or not. The lack of barite can be interpreted in two ways: a) the deposition of ore took place in an extremely euxinic environment (third-order depression) in which the sea water sulphate was completely reduced to sulphide so that a precipitation of barite was not possible; b) there was a primary absence of barium in the hydrothermal solution.

Examples: Howards Pass, Sullivan, McArthur River, Mount Isa, Hilton.

2) Rammelsberg type - stratiform, massive sulphides and bedded barites are

Table I *Summary of the different ore types included into the intracratonic basin deposits of Morganti (1981).*

Examples, after Morganti (1981)	Mac Arthur River Mount Isa Hilton	Kupferschiefer Zambian copperbelt White Pine, Michigan	Largentière, France
type of mineralization	stratiform	stratabound	stratabound
kind of mineralization	massive	disseminated	disseminated, very locally massive
footwall alteration	frequent	absent[1]	local veins in footwall rocks
ore grade (% Pb + Zn)	high (>10%)	low (<2%)	low - medium (2 - 6 %)
areal distribution	small (third-order basins)	wide (widespread transgression)	small (fault controlled clastics)
environment of host rocks	marine	marine transgression on continental red beds	deltaic, fluviatil, limnic
tectonic setting of host rocks	pre-orogen	post-orogen	post-orogen
origin of mineralization	syngenetic, submarine exhalative	diagenetic, some later remobilization and migration	late diagenetic to epigenetic
proposed nomenclature, this paper	sediment-hosted, massive stratiform	Kupferschiefer-type	lead-bearing sandstones

[1]The Rote Faeule does not represent a hydrothermal alteration.

spatially and genetically associated. Cross-cutting mineralization of the footwall sediments may or may not be present. The barite occurs as a lateral equivalent horizon of the stratiform sulphides (e.g., Meggen, Silvermines-Ballynoe, Cirque, B.C.). Barite occurs in the hanging wall of the stratiform sulphides (e.g., Gray Ore body of the Rammelsberg, Lady Loretta). Sulphide and barite are interlaminated (e.g., Tom and Jason) or irregularly mixed (e.g., upper part of the Rammelsberg ore, Alberfeldy, Scotland). To a lesser extent there are also barium silicates and barium carbonates coprecipitated with the barite (Large, 1980b).

3) Nevada type - widespread bedded and nodular barites without base metal sulphides. The stratiform barites are often hosted by cherts, cherty shales and carbonates. There is obviously no feeder-zone mineralization. The lack of base metals can be interpreted as: a) the environment of deposition was oxygen-bearing so that the base metals were oxidized and dispersed; and b) the discharge of hydrothermal solutions contained only barium (cf. Finlow-Bates, 1980, p. 152).

Examples: Nevada, Arkansas, Washington, several widespread horizons in the Macmillan Pass - Howards Pass area.

It is still an open question whether all hydrothermal solutions contained barium and base metals, and whether the presence or absence of sulphides and barite is only the result of oxidizing or reducing conditions at the site of precipitation. Another unsolved question is the identification of proximal and distal features within the Nevada type and, finally, possible lateral transitions between the Nevada and the Rammelsberg type. These problems are presently being investigated in the Macmillan Pass area.

References

Aubouin, J., 1965, Geosynclines: Developments in Geotectonics, v. 1: Amsterdam, Elsevier, 335 p.

Badham, J.P.N., 1981, The origins of the ore deposits in sedimentary rocks: *in* D.H. Tarling, ed., Economic Geology and Geotectonics: Blackwell Scientific Publications, p. 149-191.

Beyschlag, F., 1920, Zur Frage der Entstehung des Kupferschiefers: Z. dt. geol. Ges., v. 72, p. 318-328.

Bjorlykke, A. and D.F. Sangster, 1981, An overview of sandstone-lead deposits and their relationships to red-bed copper and carbonate-hosted lead-zinc deposits: 75th Anniversary volume, Econ. Geol.

Carne, R.C., 1979, Geological setting and stratiform mineralisation Tom Claims, Yukon territory: Dept. Indian and Northern Affairs, EGS - 1979-4, 30 p.

Ehrenberg, H., A. Pilger and E. Schroeder, 1954, Das Schwefelkies-Zinkblende-Schwerspatlager von Meggen (Westfalen): Beih. Geol. Jb., v. 12, 352 p.

Finlow-Bates, T., 1980, The chemical and physical controls on the genesis of submarine exhalative orebodies and their implications for formulation exploration concepts: A review: Geol. Jb., v. D40, p. 131-168.

Finlow-Bates, T. and D.E. Large, 1978, Water depth as a major control on the formation of submarine exhalative ore deposits: Geol. Jb., v. D30, p. 27-39.

Foglièrini, F., J.C. Samama, and M. Rey, 1980, Le gisement stratiforme de Largentière (Ardèche): Gisements Francais, fasc. E4, 26[e] CGI, 54 p.

Gunzert, G., 1953, Ueber die Bedeutung nachtraeglicher Erzverschiebungen in der Kupferlagerstaette des Richelsdorfer Gebirges: Notizbl. hess. Landesamt Bodenforsch, v. 81, p. 258-283.

Jung, W. and G. Knitzschke, 1976, Kupferschiefer in the German Democratic Republic (GDR) with special reference to the Kupferschiefer deposit in the southeastern Harz-Foreland: *in* K.H. Wolf, ed., Handbook of Strata-Bound and Stratiform Ore Deposits, v. 6: Amsterdam, Elsevier, p. 353-406.

Klau, W. and D. Large, 1980, Submarine exhalative Cu-Pb-Zn deposits. A discussion of their classification and metallogenesis: Geol. Jb., v. D40, p. 13-58.

Krebs, W., 1981a, The geology of the Meggen ore deposit: *in* K.H. Wolf, ed., Handbook of Strata-Bound and Stratiform Ore Deposits, v. 9: Amsterdam, Elsevier, p. 509-549.

Krebs, W., 1981b, Saxonische Pb-Zn-Ba-F-Mineralisation in klastischen und karbonatischen Gesteinen des postvariszischen Deckgebirges: Paper 133rd Meeting of the Deutsche Geologische Gesellschaft, Clausthal-Zellerfeld, September, 1981.

Lambert, I.B., 1976, The McArthur lead-zinc-silver deposit. Features, metallogenesis and comparisons with some other deposits (stratiform ore): *in* K.H. Wolf, ed., Handbook of Strata-Bound and Stratiform Ore Deposits, v. 6: Amsterdam, Elsevier, p. 535-585.

Large, D.E., 1980a, Geological parameters associated with sediment-hosted, submarine exhalative Pb-Zn deposits: an empirical model for mineral exploration: Geol. Jb., v. D40, p. 59-129.

Large, D.E., 1980b, On the geology, geochemistry and genesis of the Tom Pb-Zn-barite deposit, Yukon Territory, Canada: Dissertation Techn. Univ. Braunschweig.

Large, D.E., 1981, Sediment-hosted submarine exhalative lead-zinc deposits - a review of their geological characteristics and genesis: *in* K.H. Wolf, ed., Handbook of Strata-Bound and Stratiform Ore Deposits, v. 9: Amsterdam, Elsevier, p. 469-507.

Lydon, J.W., R.D. Lancaster and P. Karkkainen, 1979, Genetic controls of Selwyn Basin stratiform barite/sphalerite/galena deposits: an investigation of the dominant barium mineralogy of the Tea deposit, Yukon: Current Research, Pt. B, Geol. Survey Canada Paper, 79-1B, p. 223-229.

Morganti, J.M., 1981, Ore deposit models - 4. Sedimentary-type stratiform ore deposits: some models and a new classification: Geosci. Canada, v. 8, p. 65-75.

Smith, C., 1978, Geological setting of Jason and Tom deposits, MacMillan Pass area, eastern Yukon: Summary of presentation, Whitehorse Geoscience Forum, December, 1978, 5 p.

MS received September 24, 1981.