Volcanogenic Massive Sulfide Deposits (VMS)

Characteristics:

- Size and Grade: Usually small deposits with high grades of Cu, Zn, Pb, Au and Ag.
- Tonnages are widely variable.
- Metals: sources of Cu, Zn, Pb, ± Au ± Ag. High in Cd, As, Sb, Bi, Ba and Sn.
- Ore minerals: Chalcopyrite, sphalerite and galena + minor arsenopyrite, magnetite, tetrahedrite, and tennantite. Vertical and lateral zonation is sometime cyclic.
- Gangue minerals: mainly Qz, ± Calcite. Barite and gypsum are common.
- Host rocks: Submarine volcanic rocks, ranging in composition from basalts to andesites and rhyolites.
- Shape and nature of Ore body: Conformable mounds or broadly stratiform lenses of massive sulfides usually overlying a zone of stockworks. Mounds usually overlain by layers of chert and barite. Commonly interlayered with carbonaceous shales.
- Zoning:
    - i- Galena and pyrite in the upper half, with Ccp increasing into the stockwork.
    - ii- Ag in Galena increasing upwards
    - iii- Ba highest towards the top.
    - iv- $\delta^{34}S$ increases away from location of "vent" (see origin).
- Textures and primary structures:
    1- Colloform banding of sulfides with framboidal pyrite
    2- Metamorphism destroys these textures, and produces a granular ore.
    3- Soft – sediment structures
    4- Brecciation (crackle breccias).
    5- Graded bedding
- Wall rock alteration: Chloritization and sericitization.
- Age: variable, a few Archean deposits, most deposits Phanerozoic.

Types of VMS: (based on composition and predominant host rock)

1. Cyprus: Cu, small, ophiolites (Fig. 1).
2. Besshi: Cu – Zn, calcalkaline island arcs, thick greywacke sequences
3. Kuroko: Cu – Zn – Pb: more felsic volcanics, large amounts of barite and gypsum (Fig. 2).
4. Primitive: Cu – Zn, Precambrian terranes.

Origin:

Constraints:

1- Fluids most likely circulating represent sea water (salinity, and O & H isotopes), possibly mixing with magmatic water (0 – 20%) (Fig. 3).
2- Sulfides have mantle $\delta^{34}S$ values.
3- Sulfates indicate a biogenic origin.

4- Relatively low T (~ 100 – 300°C).
5- Pb isotopic data is very uniform, similar to that of mantle.
6- Ore deposits seem to be preferably associated with felsic volcanic rocks, rather than mafic ones.
7- Analogy with Black smokers and white chimneys.
8- Extreme telescoping.

Models:

1- 1-Hydrothermal origin: Sea water circulating through thick pile of volcanics (Fig. 4). Four stages (cf. Evans p. 74; Fig. 5). Works best for Cyprus type deposits.
2- Sea water mixing with magmatic (exhalative) water
3- Stanton's model: early magmatic origin, later affected by sea water circulation. Proposed to account for the higher concentration of the ores in intermediate and felsic volcanics rather than mafic ones.
4- Long lived magmatically driven convection cells of sea water + addition of metal rich magmatic solutions from the heat source over short intervals of time.
5- Exhalative origin: plumes of fluids deposit sulfides over a large area, unconsolidated sulfides then reworked into their mounds by submarine sliding, … etc. (Figs. 6 - 8).

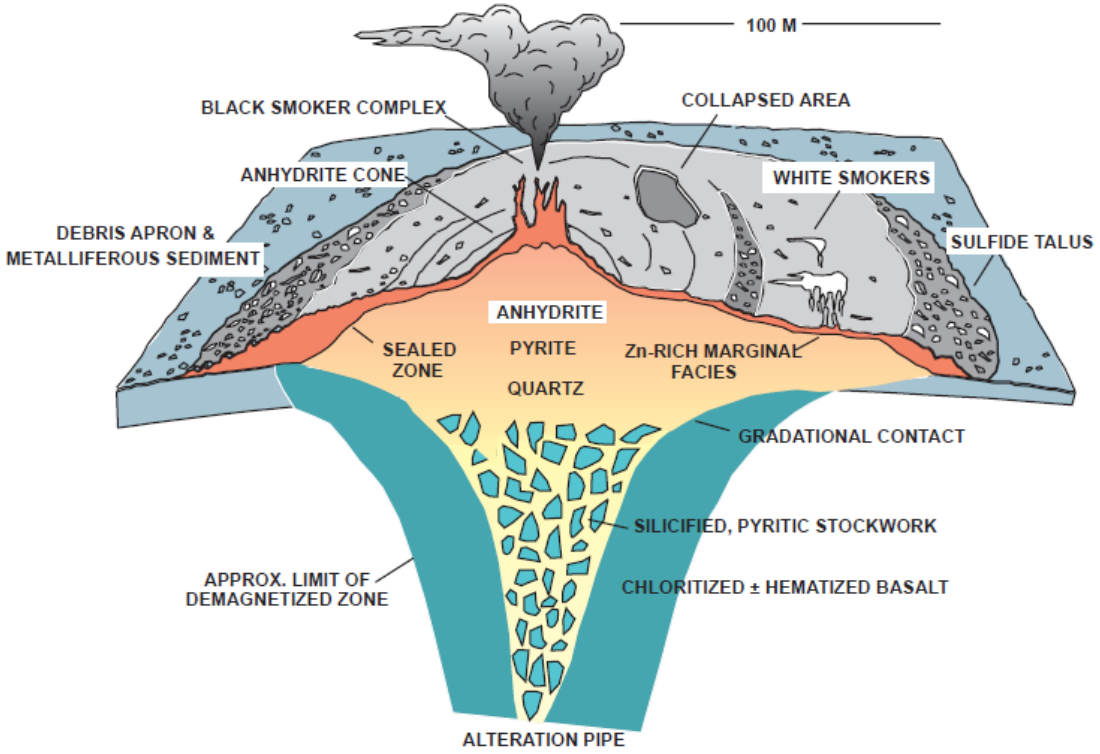

FIGURE 1. Schematic diagram of the modern TAG sulphide deposit on the Mid-Atlantic Ridge. This represents a classic cross-section of a VMS deposit, with concordant semi-massive to massive sulphide lens underlain by a discordant stockwork vein system and associated alteration halo, or "pipe". From Hannington et al. (1998).