Suggested Answers to Week 2 Assignment 1

1. How do rocks melt? Differentiate Batch melting and Fractional melting. [2 Points]

Ans: A rock anywhere in the interior (more specifically in the lithosphere) is stable as a solid because it is at any point on the curve defining the geothermal gradient. The melting curve (or the dry solidus) is above the geothermal gradient. In order that the rock should melt, the geothermal gradient must be perturbed – that is, either it move upward (pressure reduced at that temperature) or to the right (temperature to rise at that pressure). The first is possible if the material starts to move upwards (exhumation as it happens in the upward moving convection cell) and the second is possible if there is any extra input of heat (such as a thermal plume).

Batch melting is essentially equilibrium melting since the melt is in equilibrium with the solid residue in the melting process whereas fractional melting is the process by which any incremental melt generated in the process immediately gets expelled from the system without equilibrating with the solid.

2. What are trace elements? Explain their distribution behaviour during partial melting. [2 Points]

Ans: Although a trace element is generally defined as an element whose concentration is in minor amounts measurable in ppm or ppb or less. Thermodynamically, the concentration range of an element obeying Henry’s law, is a trace element. If the concentration is higher than that, the activity (thermodynamic concentration) is not linearly proportional to concentration.

In partial melting, all trace elements whose bulk distribution coefficients are less than one, will get enriched in the melt. The bulk distribution coefficient is a sum of individual mineral versus melt partition coefficients of the minerals present in the parent rock (considering the mass fraction in which they are present).

3. What are possible magmatic processes that give rise to mineralization? [2 Points]

Ans: The possible magmatic processes that give rise to mineralization are (i) early crystallization differentiation and gravitative settling, (ii) immiscible liquid segregation, (iii) Residual Liquid Injection. Most orthomagmatic deposits could be visualized as formed due to these fundamental processes with some variations.

4. Name some of the oxide and sulfide orthomagmatic deposits with examples? [2 Points]

Ans: Oxide: Chromite and Ti-V-Magnetite deposits. Example – Bushveld Complex, SA

Sulfide: Ni-Cu-PGM sulfide deposits. Example – Bushveld complex, SA; Kambalda, Australia; Sudbury, Canada

Ans: From an originally homogeneous silicate melt, which has a high solubility of sulfur, a sulfide liquid is exsolved with progress of evolution. Any chalcophile metal will get preferentially partitioned into the immiscible sulfide liquid. Depending on the ratio of the sulfide liquid to the silicate liquid, the concentration of the metal in the sulfide liquid will vary and sometimes, may attain very high value resulting in enrichment of the metal in the sulfide melt resulting in mineral deposits.

6. Indicate the temperature, pressure, depth zone in which diamond is likely to be stable. How the diamonds transported by kimberlitic magma, are still stable at shallower depths in the crust? [2 Points]

Ans: Below a thickened continental crust, at depths of about 150 to 400 km and correspondingly temperature in excess of 1000 °C and pressure in excess of 40 kilo bars, diamond is stable and form in the mantle rocks where a reducing condition must prevail. Usually diamond in these rocks, if subjected to lower pressure and temperature conditions, should get transformed to graphite. However, we see them in kimberlites now exposed at the surface. It is observed that the transformation of diamond to graphite is kinetically controlled (thus time plays an important role). We also know that diamond in the kimberlites are not product of crystallization from melt, rather are entrained solids from the melting region in the mantle. Therefore, in order that the diamond be present in these rocks (kimberlites, lamproites), the magma must ascend fast through the lithosphere.

7. Lower mantle is relatively enriched in carbon than upper mantle but doesn't likely to contain diamond. Why? [2 Points]

Ans: The main important reason is that the region in the mantle has to be in a relatively reducing condition for diamond to be stable. It is believed that parts of the mantle where the condition is oxidizing with CO₂ or carbonates stable, result from metasomatism (known as ‘mantle metasomatism’) – essentially addition of fluids and LILEs caused by deep subducting slabs.

8. What are ophiolite complexes and what types of magmatic ore deposits are expected to be present there? [2 Points]

Ans: Ophiolites are obducted ocean floor in which the sequence of peridotite, gabbro, sheeted dykes and pillow basalts along with sediments are preserved. They formed in the mantle upwelling zones (MOR) and are transported to collision zones where they are obducted. Mineralization to be expected are the VMS (as in Troodos ophiolites and Oman ophiolites) and also the ‘alpine-type chromite deposits.

9. Describe in brief the possible mechanism of genesis and type of chromite deposit found in layered mafic complexes with respect to quartz - olivine - chromite ternary system. [2 Points]

Ans: Crystallization of chromite is explainable on the basis of a ternary phase diagram with Olivine, Cromite and Silica as apices. While a parent mafic melt, in principle starts with
crystallization of olivine, the melt is enriched with Chromite with evolution of the melt and reaches the cotectic of simultaneous crystallization of chromite + olivine and with further evolution, the melt becomes rich in silica and pyroxene becomes stable. In order to have pure chromite, the melt must crystalize only chromite which is possible only if the melt enters the chromite field. This is possible only if there is mixing of the more evolved magma with a primitive part by some mixing process that may happen episodically that would explain the formation of chromitite layers repetitively.

10. Describe the settings in which magmas of granitic (felsic/calc-alkaline) composition are generated. Also, indicate the types of mineralization (of metals) that you would expect there. **[2 Points]**

Ans: Magmas of granitic (felsic / calc-alkaline) are generated mainly in convergent plate margin settings like the Island-Arc (example – the Japanese Arc) and continental arc (example – the Chilean Andes). The mineralization associated with the first type are the Kuroko-type Pb-Zn VMS deposits. Often such zones are also associated with low-sulfidation epithermal deposits of gold and silver. The continental arc settings are the store house of porphyry copper deposits and high-sulfidation epithermal deposits of copper.

11. Briefly state two broad tectonic regimes in which mineralization are associated with basaltic magmatism. Add a note on the nature of mineralization (in terms of the metals and the types of deposits) in these two regimes. **[2 Points]**

Ans: The first broad tectonic settings of basaltic magmatism is the MOR in which tholeiitic basalts are erupted on the ocean floor. These are the sites of the present day live hydrothermal systems where mineralization of Cu and Zn are taking place. Such magma crystallizing at greater depths give rise to chromite deposits which are exposed only in obducted ophiolite sequences.

12. Bring out two points of difference between Algoma-type and Superior-type BIF. **[2 Points]**

Ans: 1- The Algoma-type BIF are older – mostly in late-Archean whereas the Superior types are in Early to Mid-Proterozoic.

2. Algoma type are less extensive than the Superior-type and occur with metamorphosed greenstones

3. Algoma type have significant volcanic component compared to Superior type

(any two would do)

13. How are carbonatitic melt generated? What mechanism would you suggest for the enrichment of REEs from carbonatitic magma? **[2 Points]**
Carbonatite melts are generated by very low degree of partial melting (less than 3%) of carbonate-rich mantle ultramafic rocks, thus enriching the REEs in significant concentration. Further enrichment is brought about by fractional crystallization and immiscible separation of alkaline silicate melts.