NOTES

DENTIST'S MICRO-DRILL: A LOW-COST, TIME-SAVING, EFFECTIVE TOOL TO OBTAIN PURE MINERAL-SEPARATES (POWDER) FROM ROCKS, ORES AND MINERALS

Introduction

Mineral-separation from rocks is a time-consuming and laborious process. However, it is an essential requisite due to the need for pure mineral phases in many geological studies. These include X-ray diffraction, mineral chemistry, radio- and stable-isotopic investigations on a single phase or suite of minerals, mineral-based geothermobarometry, thermoluminiscence (TL) on TL-sensitive minerals, etc. Separation of minerals from a rock-specimen involves, sequentially: (i) crushing a large volume of it, weighing about 1-2 kg, in a stainless steel mortar with pestle into small pieces of a minimum size of 1-2 cm across, (ii) grinding these pieces in a shatter box or disc mill to obtain material of about -125# size, (iii) treating this fine-grained material with dil. HCl and desliming, followed by repeated heavy liquid and magnetic separation at different amperages on an isodynamic magnetic separator till a mineral-fraction of >90% purity is obtained, (iv) removal of impurities under a microscope so as to obtain >99% pure mineral and (v) its powdering to still finer-size of ca. -325# in a pulveriser like agate mortar for subsequent studies. This entire process takes a minimum of about a week for a mineral, with lesser time for major rock-forming minerals and small quantity, and much longer time for minor-accessory minerals and large quantity of material.

For mineral chemistry, this whole cumbersome process can be substituted by Electron Micro Probe (EMP) analysis at various spots of a mineral in a polished slab or thin-section. However, EMP is not available in many University Departments of Earth Sciences, National Institutions and R&D Organisations, mainly due to very high cost of the unit and its maintenance. Even if EMP were available, it is of no use for other mineral-based studies like XRD, isotopic, TL studies etc., as these require minerals in powder form. Furthermore, the level of precision and accuracy of EMP analysis though of satisfactory level for major elements/ oxides, is not up to the mark for trace elements. All these make mineral-separation from a rock still a critical requisite. How this can be done with a low-cost (about Rs. 15,000/-) and indigenously available tool of 'Dentist's Micro-Drill' (DMD), and some of the potential uses of its product, viz., pure mineral-powder, in diverse geological studies and their ramifications are dealt with in this 'note'.

Applications of DMD-based Mineral-separate (powder) in Geological Studies

(a) X-ray Diffractometry: Powder X-ray diffractometry (XRD) is a routine technique for mineral identification, especially when such minerals are not easily identifiable by optical microscopy. Mineral-identification by XRD is relatively easy on powder of one or two minerals rather than an admixture of many minerals, and this is mainly due to interference of characteristic diffraction peaks in case of the latter. This problem is more acute if the mineral to be identified happens to be a minor-accessory phase in a rock like ore and radioactive minerals. Due to this, the rock-powder is to be subjected to mineral separation using heavy liquid media and isodynamic separation at different amperages so as to obtain a number of fractions with each of them containing only a few (2-3) minerals. Sometimes XRD is the only technique to identify certain minerals that are very difficult to identify under the microscope, and these include clay minerals, metamict minerals and secondary minerals of uranium, besides unknown minerals. The required material for powder XRD analysis is of the order of 0.5 gm, which is sufficient to fill the open-space in sample-holder, and is much less if camera-mode is adopted. This amount of material of a single mineral from a consolidated rock can be easily obtained by treating the sample with DMD, coupled with a stereo-microscope in an operation of a few hours.

(B) Mineral Chemistry: Chemical analysis of minerals in a rock by wet chemistry gives weighted average composition whereas by EMP the weight per cent analysis can be obtained at different spots of grains of the mineral under investigation. For wet chemical analysis of major, minor and trace elements, a sample powder of 0.5-1 gm weight is usually sufficient to prepare required sample solutions, and for the Instrumental Neutron Activation Analysis (INAA) the sample requirement is of much less quantity (maximum of 50 mg). The advantage of wet chemistry using the instruments like AAS, Spectrophotometer, Flame Photometer, Fluorimeter and ICP-AES/MS or INAA over EMP is the ability of the former to analyse even trace to ultra-trace elements like rare earths, Au, Ag etc., which is beyond the capacity of the latter. The amount of sample required for wet chemistry and/or INAA can be easily obtained by DMD technique. For example, the contents of invisible precious metals of Au, Ag in sulphides and PGE in chrome-spinel and nickeliferous minerals, can be determined on mineral-separate (powder) obtained by use of DMD combined with a microscope.

(c) Geochronology: This study, based on radio-isotopic analysis for different systematics like K-Ar, Rb-Sr, Sm-Nd, U/Th-Pb and Re-Os, is carried out by a mass spectrometer on rock or mineral samples. Of late, the mineral-isochronology on minerals like zircon, monazite, titanite and rutile is gaining importance due to its utility in unraveling major temporal events in geology like dating the oldest rocks, chronological evolution of crust-mantle etc. To obtain mineral ages, the ideal equipment for analysis is an Ion Microprobe like SHRIMP that, however, is rarely available due to very high cost of the instrument and its maintenance; in India, there are hardly 3-4 units of ion probe used for geochronological investigations. The next best to this is Thermal Ionisation Mass Spectrometer (TIMS) as is for whole-rock chronology, and the amount of mineral-sample required for this can be easily obtained by DMD tool.

(d) Stable-Isotopic Study: In this, the isotopic analysis of low atomic number elements like S, C, O, H and N is carried out on minerals like sulphides, sulphates, oxides, carbonates and silicates. Results of this study have important bearing in probing aspects like genesis, physicochemical conditions of formation and alterations etc., that are critical in metallogeny-modeling. The requirement of sample for isotopic analysis by a mass spectrometer is only a few mg (<50 mg), which can be easily obtained by DMD, especially on soft minerals like sulphides, sulphates and carbonates. Furthermore, by sampling co-existing phases like pyrite-chalcopyrite, pyrite-pyrrhotite, chalcopyrite-galena etc., as well as different phases of the same mineral like pyrite, the data can be well constrained and DMD, thus, is an ideal tool to obtain samples for stable-isotopic study.

(e) Geotheromobarometry: This, based on composition of co-existing minerals in rocks, is an important facet of study in metamorphic and magmatic petrology. In metamorphic petrology, the study facilitates to determine the P-T-t-d conditions of different metamorphic facies, besides ultra-high thermal/pressure(UHT/P) metamorphism. These data are used for: (a) deducing peak metamorphic, isobaric cooling (IBC) and isothermal decompression (ITD) conditions, (b) probing clockwise (CW), anticlockwise (ACW) or counterclockwise (CCW) heating-cooling paths, (c) construction of P-T grid and pseudosections for specific bulk compostion in model systems, (d) indicating modes and mineral assemblages to be tracked through P-T space, (e) providing quantitative models for comparison with field observations and (f) understanding the effect of bulk composition in phase equilibria. Similarly, geothermobarometric data help in magmatic petrology for (i) determining the conditions of genesis of different primary magmas in the mantle, (b) indicating evolutionary patterns of primitive and parental magmatic rocks, (c) probing the chemical equilibria/disequilibria in rocks and (d) indicating the conditions of different modes of rock/mineral formation like fractionation, differentiation, assimilation, magma-mixing and liquid immiscibility. Mineral-based geothermobarometic study uses generally the major-minor elemental contents of coexisting mineral pairs, obtained by EMP analysis on minerals like garnet, olivine, ortho-/clino-pyroxenes, amphiboles, biotite, cordierite, K-feldspar, plagioclase, spinel, coesite etc. Of late, trace element-based geothermobarometers in minerals like garnet are proposed, since features like their compositional variations identify changes in reacting assemblage and reveal information not recorded by divalent major cations like Fe and Mg. As trace element determination is either not possible or associated with large percentage of error in EMP analysis, it is necessary to have mineral separates to analyse their powder for determination of trace elements by better techniques like AAS, ICP-AES/MS and INAA. To get such mineral separates in powder form, the technique of DMD coupled with a microscope offers a simple and better solution.

(f) Thermoluminescence (TL) Study: TL is the phenomenon of emission of light from a crystal (of a mineral) previously irradiated, by exposure either to naturally occurring radioactive minerals in the field [Natural (N) TL] or to artificial radioactive source in the laboratory, like gamma rays of Co-60 [Artificial (A) TL]. NTL and ATL study of geological materials has found wide applications in different branches of geology like stratigraphy, sedimentology, mineralogy, geothermometry and ore prospecting. TL study is usually carried out on TL-sensitive minerals like quartz, calcite, dolomite, fluorite, zircon and diamond. For this, about 100 mg of -100 to +140# mineral-powder is sufficient, and this amount of pure mineral-separate can be easily obtained from TL-sensitive minerals using DMD tool.

Different types and sizes of bits can be used in the Micro-Drill depending upon the mineral powder to be obtained and the complexity of intergrowth of minerals in the rock. To conclude, Dentist's Micro-Drill (preferably, coupled with a long working distance microscope) is an effective and low-cost tool to rapidly obtain pure mineral-separates (in powder form) having multifaceted applications in geological sciences, some of which are detailed above.

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DETERIORATION OF *INSITU* ROCK MASS DUE TO SPONTANEOUS COMBUSTION IN COAL MINES, MAJRI OPENCAST MINE, WCL, NAGPUR

A case of deterioration of rock mass in coal seams due to mine fires is presented here. This is a typical case wherein an old underground mine was converted to an opencast operation. Opencast mines can be mechanised to produce large quantities of coal and thereby making the operation profitable. This is the reason that some of the earlier underground mines of Coal India Limited are being converted to opencast mines. Once the open workings start, the coal formations are exposed to continuous fresh air supply. Due to the property, commonly known as spontaneous combustion, of coal, fire starts and may engulf the coal seam. This is of major concern in such operations as these fires are extremely difficult to quench e.g. Jharia Coal Field fire has a history of more than 100 years now.

Older workings or developed underground galleries pose many problems while excavating. Some of major problems faced are:

1. Spontaneous combustion (SPC) of coal seams culminating into mine fires and loss of valuable resources in addition to many other problems.
2. Excavation related problems while removing immediate overburden over such developed seams. This results in hot-hole (due to fire underground) thus rendering it difficult to place explosive in drill holes for blasting. The explosive may not perform properly if it is loaded immediately over a gallery underground due to release of gases into the underground gallery. If the drill hole has pierced into gallery, loading of explosive also becomes a nightmare. One may put excessive quantities of explosive into the hole without realising that the same is getting into the gallery below. This creates an extremely dangerous situation with formation of a bomb. The schematic diagram (Fig.1) portrays different problems encountered in the conversion to open-cast mining in coal mines.
3. Deterioration of rock mass around the workings may

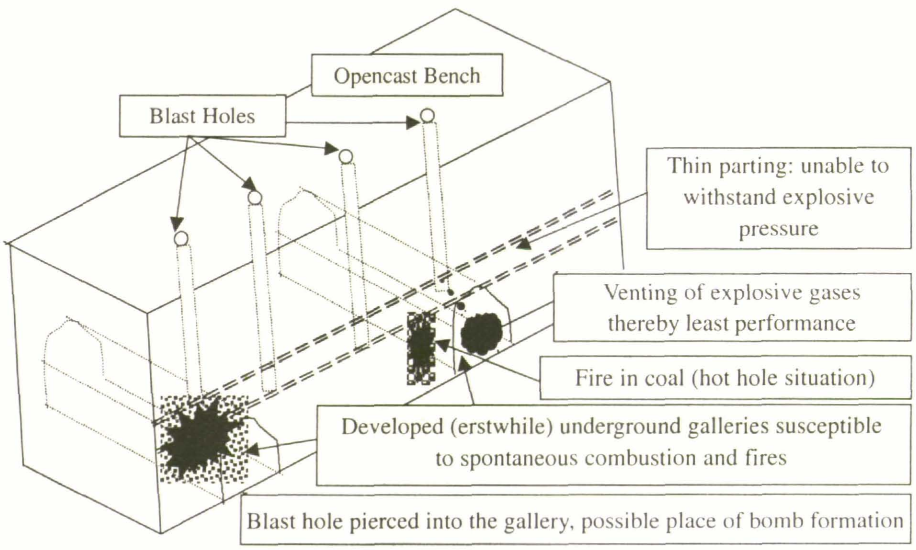

Fig.1. Schematic diagram showing problems in underground to opencast mine conversion