

Genetic Issues of Some of the Non Metallic Minerals in Lesser Himalaya

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Abstract

A brief account of the representative and workable industrial minerals namely magnesite, talc and barite in Lesser Himalaya, is presented here emphasizing their genesis. Deposits of magnesite and talc are found associated with Neoproterozoic, platform type, shelf-slope limestone-dolomite host rocks from inner Lesser Himalayan sequences. Field, textural, geochemical signatures and fluid inclusions trapped in dolomite and magnesite reveal within basin processes, in an increased burial- diagenetic environment responsible for formation of magnesite replacing dolomite. Talc is formed at the expense of magnesite and silica, and with limited dolomite involvement at transition conditions from diagenetic to metamorphism. Barite deposit is hosted within Neoproterozoic Nagthat quartzite rocks of outer Lesser Himalaya, wherein its textures, fluid inclusion, sulfur and strontium isotopic studies helped in genetic understanding.

Introduction

The reserves and prospects of non metallic minerals from Himalaya are significant not only because such materials are fundamental requirement of many industries and essential to infrastructure development, but also because their study help in understanding the geological environment and evolution. Among the four broad geotectonic divisions of Himalaya viz. Lower Himalaya, Lesser Himalaya, Central Himalaya and the Tethys Himalaya, much of the economic minerals are located in the Lesser Himalaya which is largely formed of the Precambrian elements of the Indian shield (Valdiya, 1995). The non metallic minerals in Himalaya are particularly hosted within the sedimentary sequences with only graphite occurring in the crystallines. Present discussion briefly focuses on magnesite, barite and talc from the sedimentary sequences of Lesser Himalaya emphasizing their formation and evolution. Various studies including incident light and scanning electron microscopy, geochemical work, fluid inclusions microthermometry and Raman spectroscopy has been vital for this purpose.

Regional Geology

The Lesser Himalaya, demarcated by the Main Boundary Thrust (MBT) in the south, and Main Central Thrust (MCT) in the north, represents a distinct lithotectonic unit of the Himalaya. This is broadly divisible into Inner Lesser Himalaya and the Outer Lesser Himalaya, having basement of the crystallines representing Indian cratonic rocks. The Lesser Himalayan sequences were deposited from Paleoproterozoic to Cambrian age in marine conditions on the passive margin setting of Indian continent (Valdiya, 1980; Srivastava and Mitra, 1994; Ahmad, 2000, Miller 2000; Celerier, 2009). The Inner Lesser Himalaya

sediments are the lower flysh and quartz arenites with basic volcanics, and the upper carbonate shale assemblages. The 1800 ma old Berinag Formation constitute the lower most sequence of the Inner Lesser Himalaya (Miller, 2000), overlain by Chakrata and Rautgara Formation, Neoproterozoic Deoban Formation- mainly the carbonates and above them Mandhali Formation consisting slate and carbonates. The outer Lesser Himalaya is folded sequence of sedimentary rocks comprising 850 ma turbidites of Chandpur Formation, overlain successively by Nagthat quartzites, Blaini conglomerates, Neoproterozoic Krol Formation which is largely calcareous, and above it Cambrian age elastic sediments of the Tal Formation. A number of the klippen of the crystalline rocks present in Lesser Himalaya are result of the thrusting of basement rocks over the sedimentary succession. Present focus is on the magnesite-talc which is hosted within the carbonates of the Deoban Formation, and on the workable barite mineralization occurring in the Nagthat quartzite host rocks . The Deoban Formation is a thick succession of stromatolite bearing, siliceous dolomite and dolomitic limestone with intercalated bands of blue limestone and grey slates.

Magnesite-Talc Mineralization

Deposits of magnesite are found associated with Neoproterozoic, platform type limestone-dolomite host rocks from inner Lesser Himalayan sequences, although minor magnesite occurrences are associated with ophiolitic suits in Indus Suture Zone. Sizable talc deposits are also found at various places in the Deoban Formation, hosted within high Mg carbonates. Their mining by open pit method is operational particularly in Kumaun Himalaya. Earlier work (Valdiya, 1968; Safaya, 1986; Sharma and Joshi, 1997) carried out studies on the carbonate hosted magnesite from Almora mainly for its depositional environment and genesis. However, the origin of these magnesite deposits has been variously discussed as synsedimentary, biogenic, hydrothermal and syndiagenetically replaced mineralisation. Updated data has helped to comprehend the origin of this magnesite. Thick bands, lenses and pockets of dirty white to pink colour, fine to very coarse grained stellate magnesite are found within the dolomite of the Deoban Formation. In addition, minor chert, carbonaceous material, and sometimes iron and sulphides are associated with magnesite and dolomite. The stromatolites are inevitably associated with magnesite, inferring that they facilitated the precipitation of magnesium carbonates with a rise in total Mg^{2+} in restricted water. Petrographic observations show that magnesite blades are either randomly oriented , or crystallized into spherulitic texture. The magnesite and dolomite exhibit a general sharp contact, but the irregular contacts are not uncommon wherein replacement of dolomite by magnesite is seen. Successive replacement from calcite to magnesite is also noticed elsewhere (Radvanec et al., 2001). Fine grained vein magnesite, infilling fractures and observed at few places is result of later recrystallization. Talc occurs as irregular patches or pockets in these carbonate host rocks, showing close association with magnesite and restricted with dolomite. Bands, intercalations and pockets of talc also occur at the contact of dolomite and magnesite. The magnesite, quartz and talc are intimate partner in an assemblage, which shows development of talc at the expense of magnesite and silica. Chert flakes and the talc flakes are interleaved. Further details of the grain relations are evident in SEM study. The fluid inclusion microthermometry was carried out at the fluid inclusion laboratory of Wadia Institute of Himalayan Geology, Dehradun, and using calibrated LINKAM THMSG 600 stage

fitted onto the Nikon E600 microscope. Fluid inclusions calculations are based on Flncon program of Brown (1989), and the salinity estimates on the tables of Bodnar (1993). The fluid inclusions have been studied in dolomite, magnesite and gangue quartz. Fluid inclusions are abundant in clusters and trails. Fluid inclusions trapped in dolomite and magnesite, are biphasic aqueous inclusions. A systematic increase in estimated salinity from about 7.5 to 19 NaCl wt% eq., is result of increased burial and longevity of the residence of fluids in the basin. This was linked to Mg enrichment and magnesite formation. The studied trapped aqueous brines represent remnants of basinal fluids having composition of $H_2O-NaCl \pm KCl \pm MgCl_2 \pm CaCl_2$. The range of the salinity from about 2 to 17 wt% NaCl eq. is identified for basinal fluids (Radvanec et al., 2001; Huraiova et al., 2002). It is known that saline fluids are invariably present in most of the sedimentary basins, and majority of mineral resources in such basins have been affected by these basinal fluids. The relation between final melting temperatures and the homogenization temperatures are poorly systematic (Fig. 1), these are interpreted to represent mixing of the basinal fluid with meteoric water, though partly reset of early inclusions can not be completely ruled out. Localized flux of the CO_2 occurred because of mineral reaction forming talc after magnesite/dolomite and quartz (Slaughter et al., 1975). The geochemical signatures in magnesite and talc do not invoke any external flux of Mg carrying fluid in talc formation (Sharma et al., 2008), this is also substantiated by the fluid inclusions data of dolomite and magnesite suggesting within basin processes.

Barite Mineralization

Barite mineralization in Himalaya invariably occurs in sedimentary formations, much of it in the Lesser Himalaya with only limited barite reported from the Tethyan sediments. The barite in Tethyan sedimentary rocks from Kumaun Himalaya is suggested to be structural controlled hydrothermal mineralization (Sinha, 1977), as corroborated by the minor sulphide mineralization associated with it. Majority of barite is found in the Nagthat Quartzite, Krol-Tal Formations of Lesser Himalaya, and minor barite occurs in the Great Limestone. These barites are not associated with large scale sulphide mineralization, although at a few locations barite is found as gangue in an assemblage consisting minor sulphides in veins. Workable barite occurs in veins, beds, lenticles and pockets in the Nagthat quartzite rocks wherein its concordant as well as discordant relation are seen with the hosts. The host Nagthat quartzites are medium to fine grained texturally and mineralogically mature sandstones which represent moderately sorted, subarkosic to sublithic arenite with subordinate amounts of fine-grained quartz arenite and quartz wacke. The geochemical evidences coupled with paleo-current direction suggest that the source for the host Nagthat siliciclastics were possibly southerly situated Banded Gneissic Complex of Aravali- Bundelkhand craton (Islam et al, 2002; Verma and Sharma, 2007). The depositional characters of various Lesser Himalayan barites and a general absence of igneous activity in their neighbourhood are matching for their genetic environment. The quartz grains show bimodal distribution with common presence of detrital quartz porphyroclasts and the finer recrystallized polycrystalline grains. The euhedral to subhedral grains of barite also show varied degree of recrystallization and formation of fine grains. Sutured marginal contacts between the grains of barite and host rock infer sharing of the depositional history. Fluid inclusion study carried out on barite show that the primary inclusions in barite grains are filled with saline aqueous fluid. Both monophasic and biphasic

inclusions are noticed. Their final ice melting temperatures correspond to a salinity < 15 wt NaCl eq., and the homogenization to liquid phase occurred at $170 \pm 40^\circ$ C. Fluid inclusion study support participation of moderately warm, saline aqueous fluid in barite deposition. Strontium isotope ratios in barite are useful in understanding its genesis (Barbeiri et al., 1984; Marchev et al., 2002). The abnormally high $^{87}\text{Sr}/^{86}\text{Sr}$ ratios: 0.720448 ± 0.000034 to 0.728637 ± 0.000039 , are obtained for the Tons valley barite (Sharma et al., 2003) suggesting participation of the material from highly radiogenic crustal source. The material derived from gneissic rocks of BGC is also likely to be enriched in radiogenic strontium isotope because weathering products of Precambrian shield areas are rich in radiogenic strontium, with $^{87}\text{Sr}/^{86}\text{Sr}$ ratios varying from 0.712 to 0.730 (Holland, 1984). The strontium isotope geochemistry of the barite mineralization present in quartzites of Aravali Super Group overlying BGC also show high $^{87}\text{Sr}/^{86}\text{Sr}$ contents (Deb et al., 1991). We have also carried out sulphur isotope analyses of the barite. Obtained high $\delta^{34}\text{S}$ values in barite substantiate absence of magmatic fluid participation in initial barite formation. These probably points to the participation of Proterozoic sea water in barite formation (Nielsen 1979; Schidlowski 1988). It is interpreted that the leaching of Ba from K- feldspar of the source BGC rocks possibly supplied Ba^{2+} for barite formation. During the fractional crystallization of igneous melts, Ba^{2+} gets mainly confined to K-bearing minerals because of the similarity in the ionic radii of these two elements. Therefore, feldspars and micas are enriched in Ba^{2+} (Barbeiri, 1989), thereby granites usually contain 400- 10,000 ppm of Ba content and the K- feldspar in granites may consists upto 6% Ba in its structure. Hence, the consideration of various parameters infer fluid mixing model for the initial barite formation (Fig. 2). They recommend mixing of the marine and crustal material and participation of saline aqueous fluids in barite formation, may be linked with diagenesis of host sedimentary rocks.

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References

- Ahmad, T., Harris, N., Bickle, M., Chapman, H., Bunbury, J., and Prince, C., (2000) Isotopic constraints on the structural relationships between the Lesser Himalayan Series and the High Himalayan Crystalline Series, Garwhal Himalaya: Geological Society of America Bulletin, v. 112, pp. 467–477.
- Barbeiri, M., Masi, U. and Tolomio, L. (1984) Strontium geochemical evidence for the origin of the Barite deposit from Sardinia, Italy. *Econ. Geol.*, v. 79, pp.1360-1365.
- Bodnar, R. J. (1993) Revised equation and table for determining the freezing point depression in H_2O -NaCl solutions. *Geochim. Cosmochim. Acta*, v. 57, pp. 683-684.
- Brown, P. E. (1989) Flincor: a microcomputer program for the reduction and investigation of fluid inclusion data. *Am. Mineral.*, v. 79, pp. 1390-1393.
- Celerier, J., Harrison, T.M., Webb, A.A.G. and Yin A. (2009) The Kumaun and Garhwal Lesser Himalaya, India: Part 1. Structure and Straitigraphy. *Geol. Soc. Amer. Bull.*, v. 121, pp. 1262-1280.

- Deb, M., Hoefs, J. and Boumann, A. (1991) Isotopic composition of two Precambrian stratiform barite deposits from the Indian shield. *Geochim. Cosmochim. Acta.*, v. 55, pp. 303-308.
- Holland, H.D. (1984) *The chemical evolution of the atmosphere and oceans*. Princeton Univ. Press, Princeton, N.J., 582 p.
- Huraiova, M., Vozarova and Repcok, I. (2002). Fluid inclusion and stable isotope constraints on the origin of magnesite at Burda, Ochtina, Lubenik and Ploske deposits (Slovakia, Western Carpathians). *Geologica Carpathica*, v.53, pp.98-99.
- Islam, R., Ghosh, S.K. and Sachan, H.K. (2002) Geochemical characterization of the Neo-Proterozoic Nagthar siliciclastic rocks, NW Kumaun lesser Himalaya: implications for source rock assessment. *Jour. Geol. Soc. India*, v. 60, pp. 91-105.
- Marchev, P., Downes, H., Matthew, F. and Thirlwall, R.M. (2002) Small-scale variations of $^{87}\text{Sr}/^{86}\text{Sr}$ isotope composition of barite in the Madjarovo low-sulphidation epithermal system, SE Bulgaria: implications for sources of Sr, fluid fluxes and pathways of the ore-forming fluids. *Mineral. Deposita*, v. 37, pp. 669-677.
- Miller, C., Klotzli, U., Frank, W., Thoni, M., and Grasemann, B., 2000, Proterozoic crustal evolution in the NW Himalaya (India) as recorded by circa 1.80 Ga mafic and 1.84 Ga granitic magmatism: *Precambrian Research*, v. 103, pp. 191–206,
- Nielson, H. (1979) Sulphur isotopes. In Jagar, E. and Hunziker, J.C. (eds.) *Lectures in isotope geology*. Springer-Verlag, Berlin, pp. 283- 311.
- Radvanec, M. and Prochaska, W. (2001) Successive replacement of Upper Carboniferous calcite to dolomite and magnesite in Dubrava magnesite deposit, Western Carpathians, Slovakia. *Mineralia Slovaca*, v. 33, pp. 517-525.
- Safaya, H.L. (1986) Magnesite deposits of Kumaun Himalaya, Uttar Prades-Depositional environment, genesis and economic utility. *Geol. Surv. India Misc. Pub.* 41(VI), pp. 150-178.
- Schidlowski, M. (1988) A 3800-million year isotopic record of life from carbon in sedimentary rocks. *Nature*, v. 333, pp. 313-318.
- Sharma, Rajesh and Joshi, M.N. (1997) Fluid of magnesitization : Diagenetic origin of Bauri magnesite, Kumaun Lesser Himalaya, *Curr. Sci.*, v. 9, pp 789-792.
- Sharma, Rajesh, Verma, Priti and Sachan, H.K. (2003) Strontium isotopic constraints for the origin of barite mineralisation of Tons Valley, Lesser Himalaya. *Curr. Sci.*, v. 85, pp. 653-656.
- Sharma, Rajesh, Joshi, Prabha and Pant, P.D. (2008) The role of fluids in the formation of talc deposits of Rema area, Kumaun Lesser Himalaya. *Jour. Geol. Soc. India*, v. 73, pp.237-248.
- Sinha, A.K. (1977) A discovery of barite and associated polymetallic mineralization in Tethyan zone of Higher Garhwal and Kumaun Himalaya. *Him. Geol.*, v. 7, pp. 456-463.
- Slaughter, J., Kerrick, D.M. and Wall, V.J. (1975) Experimental and thermodynamic study of equilibria in the system $\text{CaO-MgO-SiO}_2\text{-H}_2\text{O-CO}_2$. *Am. Jour. Science*. v. 275, pp.143-162.
- Srivastava, P., and Mitra, G., 1994, Thrust geometries and deep structure of the outer and lesser Himalaya, Kumaun and Garhwal (India): Implications for evolution of the Himalayan fold-and-thrust belt: *Tectonics*, v. 13, pp. 89–109,
- Valdiya, K.S. (1968) Origin of the magnesite of southern Pithoragarh, Kumaun Himalaya, India. *Econ. Geol.*, v. 63, pp. 924-934.

Valdiya, K.S. (1980). Geology of Kumaun Lesser Himalaya. Wadia Institute Himalayan Geology, Dehra Dun, 288 p.

Valdiya, K. S. (1995) Proterozoic sedimentation and Pan- African geodynamic development in the Himalaya. Precambrian Res., v. 74, pp 35-55.

Verma, P. and Sharma, Rajesh (2007). Primary to re-equilibrated fluids and geochemical signatures for the evolution of Nagthat Siliciclastics in Tons valley, Lesser Himalaya, India. Jour. Asian Earth Sci., v. 29, pp. 440-454.

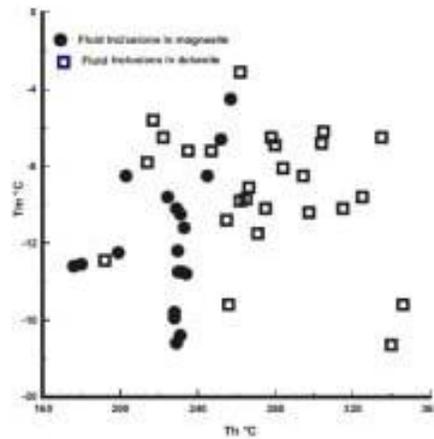


Figure 1: Tm vs Th plots of the aqueous biphasic fluid inclusions in dolomite and magnesite.

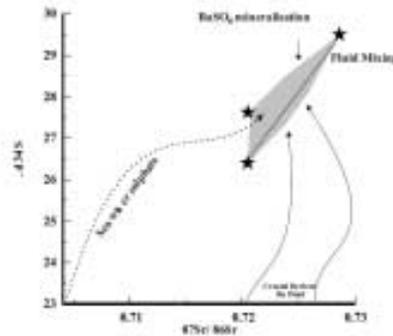


Figure2: Diagram illustrating mixing of the two fluids for the barite formation as deduced from Sr and S isotope signatures.