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Red and violet gahnite (spinel) occurrences in Ganesh Himal (central Nepal): their chemisty, inclusions and microthermometry

C. F. Uhlir [1], K. Hasenberger [2], E. C. Kirchner [2]

1Department of Geology and Palaeontology, University of Salzburg,
Hellbrunner Strasse. 34/III, 5020 Salzburg, Austria
2Department of Mineralogy, University of Salzburg
Hellbrunner Strasse. 34/III, 5020 Salzburg, Austria

ABSTRACT

The red and violet gahnites occur within dolomite marbles of medium grade amphibolite facies in the Ganesh Himal area, central Nepal. The dolomites are part of the Higher Midland Formation and lie at the northern limb's eastern end of the Kunchha-Gorkha anticline within the MCT zone of Le Fort (1975). Both gahnites ($ZnAl_2O_4$) show a chemical zonation with various contents of Cr, Mg and Fe. The red colour is most probably caused by chromium. The inclusions containing fluids have ideal negative crystal shapes or are irregular. Beside them, various solid inclusions are also found. The fluids of the two- or three-phase inclusions contain H_2O and CO_2. Two generations of inclusions varying in the content of CO_2 indicate a trapping at different PT condition or a water loss of the high CO_2 inclusions during some tectonic event.

INTRODUCTION

The world-wide unique gemstone, red gahnite, was discovered in 1994 by the first author during preliminary studies on the geology and geomorphology of the Ganesh Himal (Central Nepal). At that time, the finding was already known to the staff of the Nepal Metal Company and was described as *rato dhunga* or "ruby" of the dolomite Bed No. 2 (Fig. 1), but the minerals of this outcrop are so small (up to 5 mm diameter) that they were not of interest to them. Investigations on the first samples showed that they are red spinels of gahnite composition. During the second field investigation in 1995, gem quality violet gahnite (up to 10 mm diameter) was found within the other dolomite bodies (Bed No. 1, 2 and 3, Fig. 1) of the Lari valley. This paper describes the geology and petrography of the gahnite occurrences and the gahnite's chemistry, inclusions and microthermometry. It is not yet determined whether this occurrence is of economic value or not, but now it is confirmed that Nepal has unique gemstone occurrences.

GEOLOGICAL SETTING

The dolomite-marbles, containing red and violet spinel of gahnite composition, are part of the Higher Midland Formation (Upper dolomites of Ghandpokhra-Udi) of Le Fort (1975) in central Nepal, also called Upper Nawakot Group (Malekhu Limestones of Stocklin, 1980). They are most probably of Permo-Carboniferous age (Colchen, 1987).

Tectonically, the formation lies on the northern limb's eastern end of the broad Kunchha-Gorkha anticline, and dips slightly N to NE (increasing dip toward the north). The Upper Nawakot Group is part of the intracontinental Main Central Thrust (MCT) zone . The MCT-zone, Plio- to Pleistocene, is explained as a formerly active, large scale (up to 7 km wide) syn- and post-metamorphic shear zone (Le Fort, 1975; Copeland et al., 1991). The entire volume of rock affected by the thrusting displays a strongly planolinear fabric. Frequently within dolomite rocks, there are small and large scale boudinage structures. The pod-like shape of the upper dolomites of Ghandpokhra-Udi is due to large scale boudinage

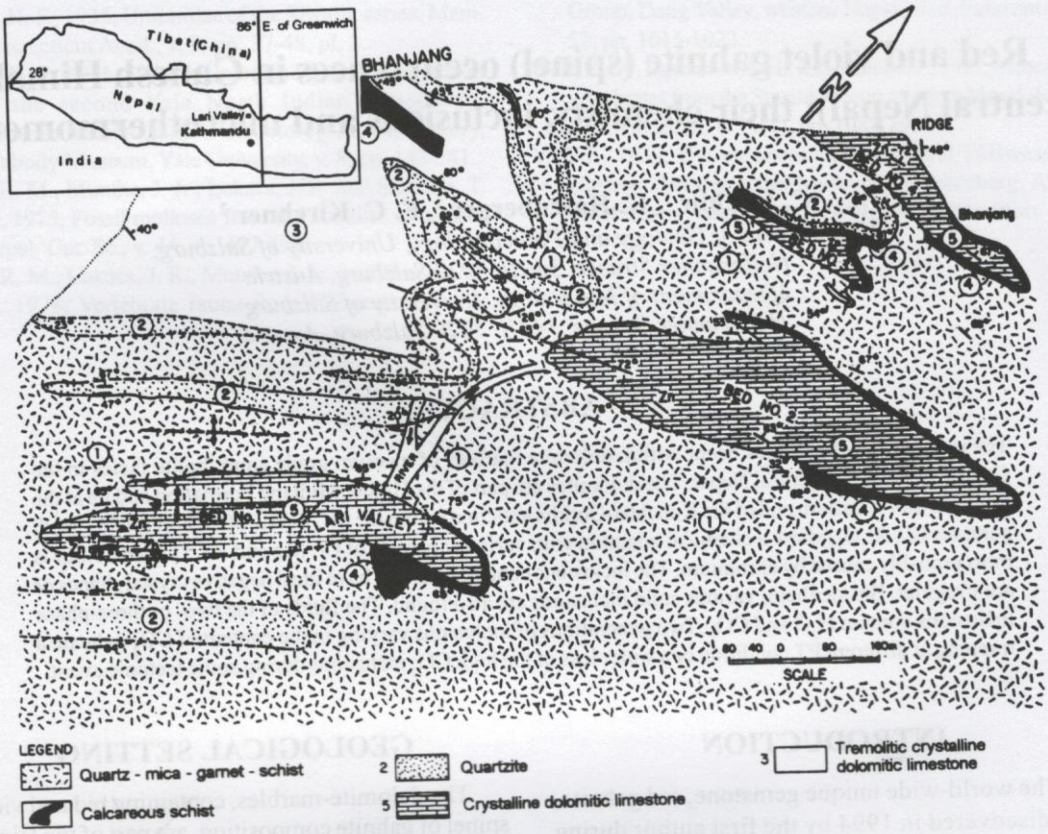

Fig.1: Geological map of the zinc-lead deposit of the Lari Valley, Ganesh Himal (after Shrestha et al. 1993)

(personal communication with Allen M. Bassett; Smith et al., 1997).

The polyform Tertiary to Pliocene metamorphism (Copeland et al., 1991) can be divided into two main stages and a following diaphthoresis (Pêcher, 1977, Macfarlane, 1992). The grade of metamorphism is increasing towards the north from green schist facies to middle/upper amphibolite facies. Due to this phenomenon the metamorphism seems to be inverted (Le Fort, 1975; England et al., 1992).

PETROGRAPHY AND MINERALOGY OF GAHNITE-CONTAINING DOLOMITES

Within a folded rock sequence of dolomite, quartzite, calcareous schists, amphibolite and garnet-quartz-mica-schists (with kyanite in quartz veins), the dolomites are the country rock of the lead, zinc, copper, (Shrestha et al., 1993) and corundum mineralisations that are of great economic value and intensely investigated (Baba, 1982; Bassett, 1984; Harding and Scarratt, 1986; Kiefert and Schmetzer, 1996; Shrestha et al., 1993; Chakrabarti, 1994; Smith, et al., 1997). The metamorphism of this series is a medium-grade amphibolite facies according to the occurrence of kyanite and staurolite (Shrestha et al., 1993).

In the Lari valley the dolomites occur as elongated lenses up to 150 m thick and up to 1 km long. The milky white, medium to fine sugary dolomite contains massive and finely dispersed sulphide mineralisations of zinc, lead, iron and copper. The pure dolomite is intercalated by greenish grey mineral-rich layers, which were originally aluminous clay interlayers of a dolomitised marine limestone formation (Bassett, 1984). Within the red gahnite-bearing layer (Fig. 2) of Bed No. 2, brownish

Fig. 2: Red Gahnite (chrome-containing zinc-spinel) in dolomite with quartz of Bed No. 2, size of the crystals 2-3 mm.

orange phlogopite, blue kyanite, green fuchsite, white margarite, quartz, colourless apatite, talc and minor sphalerite, pyrite and rutile (Smith, et al., 1997) are found. The violet gahnite (Fig. 3) of Beds No. 1, 3 and 4 occur within the pure white dolomite mostly within small pods of spathic calcite and quartz (in Bed No. 1 sometimes associated with yellow sphalerite).

MICROPROBE ANALYSIS

The gahnite samples analysed by microprobe (JEOL JXA8600) are specimens from Bed No. 1 (violet, Fig. 3) and Bed No. 2. (red, Fig 2). The gahnites (zinc is partially substituted by Mg and Fe; Al is partially substituted by Cr) plot within the isomorphous series of spinel ($MgAl_2O_4$) and gahnite ($ZnAl_2O_4$) (Deer et al., 1992). Both gahnites show a chemical zonation varying in the contents of Mg, Fe and Cr. No other trace elements have been found. The red gahnite in Fig 4 is very inhomogeneous and shows a clear zonation in its central part. The wt % of Cr_2O_3 varies from the dark to the light areas between 1.0% (d, d´) and 3.5% (h, h´ and h´´). The MgO ranges in the same areas between 3.5% (d, d´) and 1,5% (h, h´ and h´´). The FeO is constant is in average around 0.5%.

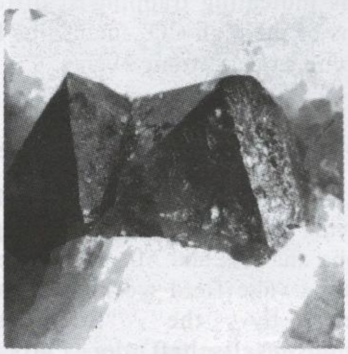

Fig. 3: Violet Gahnite (magnesium-containig zinc-spinel) in white sugar-grained dolomite of Bed No. 1, size of the crystals 5 mm.

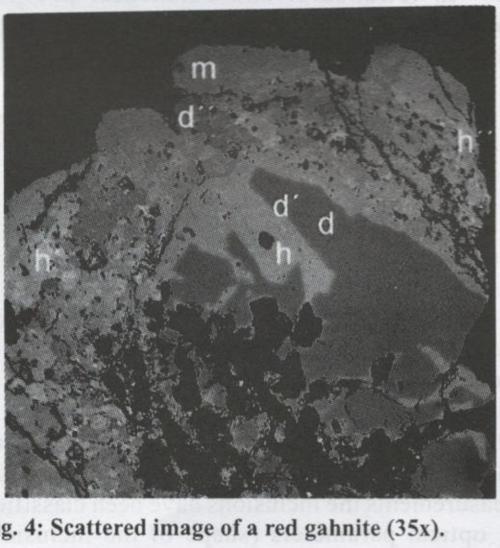

Fig. 4: Scattered image of a red gahnite (35x).

The violet gahnite in Fig 5 shows a significant zonation between its core (k, d) and a very thin light

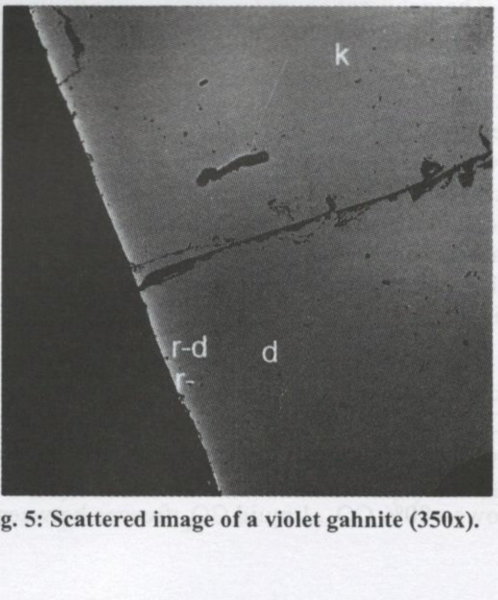

Fig. 5: Scattered image of a violet gahnite (350x).

coloured border (r-d, r-). The oxide wt % of Cr_2O_3 is in average around 0,2%. The MgO ranges between its core and the very thin light coloured border between 5,1% (k, d) and 0,9%(r-d, r-). The FeO ranges in the same areas between 1,6% (k, d) and 0,2% (r-d, r-).

The colour variation of the red to violet gahnite is most probably caused by varying contents of the trace elements and superimposition of the absorption bands of Cr^{3+} in octahedral position and Fe^{2+} in tetrahedral and octahedral position (Schmetzer et al., 1989), spectral investigations are in progress.

MICROTHERMOMETRY AND INCLUSIONS

Fluid inclusions have been studied systematically by microthermometric methods (Roedder, 1984, Shepherd et al., 1985) with a Linkam THMSG800 heating-freezing stage mounted on an Olympus BH2 microscope. Inclusions in spinel are sufficiently visible in double polished sections with thickness around 500 µm, although the samples become very dark during heating. Prior to microthermometric measurements the inclusions have been classified on optical parameters (shape of the inclusion, location in the crystal, size of the vapour phase).

The inclusions have ideal negative shapes as well as irregular shapes with sharp edges and long projections. They occur in trails and clusters and are estimated as "pseudo secondary". Clearly single, and therefore "primary inclusions" (Roedder, 1985), never could be seen. Secondary inclusions have been found in healing structures as interconnecting tubes and isolated dots of inclusions (like "healing feathers" in rubies, Peretti et al, 1995). Various solid inclusions require further investigations (Fig. 6).

The inclusions show two or three phases at room temperature and contain H_2O_L and $CO_{2V} \pm CO_{2L}$. Liquid CO_2 often becomes visible on cooling. The volume of CO_2 is 20-50% in most of the inclusions. Another less common group shows ~80% CO_2. Liquid CO_2 freezes between -95 and -105°C and thawe between -58.4 and -56.8°C. The data indicate a low content of CH_4 and/or N_2 (Table 1).

Due to the smallness of the inclusions (5-30 µm), the observation of daughter minerals and eutectic points, the melting temperatures of ice and clathrates could very rarely be observed; whereas freezing, melting and the homogenisation of CO_2 between 362 and 467°C (into the liquid and the vapour phase) could be clearly seen. Decrepitation in some cases only occurred between 350 and 370°C (Table 1).

Two-phase CO_2 and H_2O-containing inclusions show ice melting at -9,2°C and homogenisation at 280°C into the liquid phase. Secondary inclusions with an ideal negative shape homogenised between 51 and 55°C.

One-phase inclusions developed a vapour bubble on cooling which disappeared at 0°C. Large round inclusions (50-150 micron) containing one or several gas bubbles occur in clusters. The bubbles grew on cooling and slowly died out at +50°C, leaving brown dendrites inside the cavity.

Pressure corrections for 2 - 6 kbar have been calculated with FLINCOR (© 1988, 1989 Philip E. Brown). Although the homogenisation temperature (TH values) of CO_2-bearing inclusions are in the same range, the calculated trapping temperatures of high - CO_2 inclusions are far higher than those of the low CO_2 inclusions. There are either two generations of inclusions indicating trapping at different PT conditions or the high CO_2 inclusions have lost water during some tectonic event.

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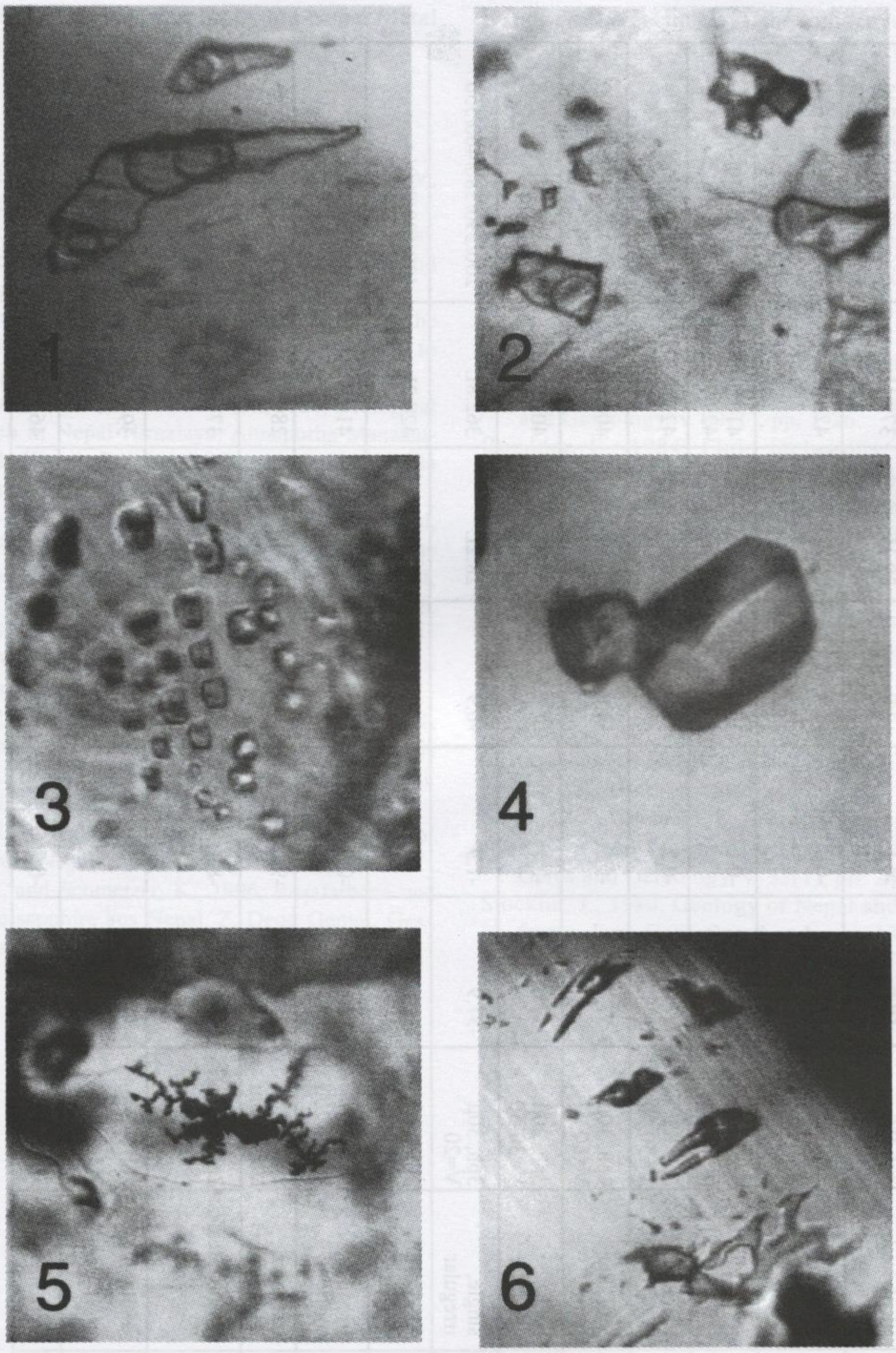

Fig. 6: Interior views of red and violet gahnite. 1. Three-phase inclusion in a red gahnite (300x), 2. Trail with irregular two-phase inclusions in a red gahnite (300x), 3. Cluster of one-phase aqueous inclusions in a red gahnite (300x), 4. A tiny apatite (?) crystal in a violet gahnite (300x), 5. Dendritic solid within an empty inclusion after heating (300x), 6. Trail of inclusions crossing the zoned margin of a red gahnite (75x).

Table 1: Microthermometric data of fluid inclusions in gahnite from the Lari valley, Ganesh Himal, central Nepal

SNC	Condtn/Shape	Phases/Vol.	TMCO$_2$	TMice	TMcl	THCO$_2$	THtot	TT
1.2 violet	ideal, trail	3ph RT V=50, 10µ	-58.0	-0.1	+2.8	29.1L	379.1L	270/380/500/620/740
2.1 violet	ideal, trail +18°C V=50, 30µ	2ph RT, eph	-58.4	-0.4	+3.9	22.3L	425.3L	240/350/450/560/670
3.1 violet	ideal, cluster	3ph RT V=80, 5-10µ	-57.5	-0.1	+9.9	26.5L	410.5 420.9L	410/600/790/-/-
4.1 violet	ideal, cluster	3ph RT V=50,20µ	-57.5	-0.2	+8.4	26.9L	425.9L	260/380/500/620/-
9.1 violet	trail, flat round	3ph, 30µ, V=50	-57.3	-5.5	+4.9	24.8L	404.9L	250/360/470/580/690
10.1 violet	trail, irregular	3ph, 20µ, V=30-50	-57.6	-2.1	+7.0	24.8L	404.8L	250/370/480/590/710
10.2 violet	single, irregular	3ph, 30µ V=20	-57.9	-1.9	+6.9	28.2L	362.8L	200/290/380/460/550
5.1 red	irregular, cluster	3ph RT V=80, 10-20µ	-58.0			27.2L	420.2L	400/600/800/-/-
5.2 red	irregular, trail	3ph RT V=80, 20µ	-58.1	-0.2	+9.8	26.9L	416.9V	400/600/800/-/-
6.1 red	irregular cluster, H$_2$O	2ph RT V=30, 50µ		-9.2			280.1L	430/510/580/660/-
6.2 red	single, ideal	2ph RT, 3ph -8°C V=80, 5µ	-56.8	-8.1	+4.3	-0.2L	374.1L	230/360/480/610/-
7.1 red	single, ideal	2ph RT, 3ph -19°C V=60, 10µ	-57.6			-9.4L	390.3L	200/310/430/550/670
8.1 red	trail, ideal	3ph, 10µ	-56.9	-6.7	+9.7	24.6L	467.5V	380/570/750/-/-/

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