SHORT COMMUNICATIONS

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Corundum, altering to margarite, in amphibolites from Dir, West Pakistan

PINK to pale purplish corundum crystals, generally less than 15 mm but occasionally reaching 6 cm in length, sometimes idiomorphic, are found sparsely disseminated in a dark grey tremolite rock (amphibolite) associated with small ultrabasic intrusions (?sills) at Timurgara, Dir, West Pakistan (34° 48′ N., 71° 50′ E.). The corundum-bearing amphibolites form bands in contact with pyroxenites and serpentinites intruded into banded hornblende gneisses (Jan *et al.*, 1969); rarely, the amphibolites themselves have a gneissose texture. The banded gneisses are composed of plagioclase, hornblende, epidote (up to 50% in some rocks), garnet, and minor quantities of iron ore and rutile. The rocks are veined, wedged, and tongued, and are mainly metasedimentary in origin. Other intrusions of granite and, most commonly, dioritic and noritic rocks are found in the area. The latter are composed of plagioclase, bronzite, clinopyroxene, hornblende, quartz, biotite, iron ore, and apatite; such rocks are abundant to the north-east of the area in upper Swat.

It is worthy of note that Pascoe (1950) described the rocks of the Timurgara area as crystalline limestones interbedded with quartzose and hornblendic schists, associated with foliated granite, being replaced northwards first by hornblende schists, then by hornblende gneiss, and later by quartz-diorite. He goes on to state that 'some, at least, of the metamorphic beds appear to be of sedimentary origin and recall the metamorphic series of the Jagdalak ruby mines'. Jagdalak, in Afghanistan, is some 130 miles west-south-west of Timurgara.

The corundum is of interest because of its occurrence in amphibolite and the fact that it is always enclosed in a complex 'envelope' of secondary minerals; these envelopes also occur devoid of corundum crystals. To quote Pascoe (1950) again: 'Barrington Brown and Judd note that "the rubies of [the Mogok series], Burma, when found *in situ* in the limestones, are usually seen to be enveloped in a mass of materials produced by the alteration of their superficial portions. Nearest to the gem is a zone of diaspore, . . . found to pass insensibly into various hydrous aluminium silicates – margarites and other clintonites, vermiculites, muscovites, kaolinites, etc. . . ".'

Deer *et al.* (1962*b*) summarize the modes of occurrence of corundum in igneous and metamorphic rocks and it would seem that very localized desilication of Al-rich (?para) amphibolites by, usually, the ultrabasic intrusions might best explain the present occurrence. However, the amphibolite is not typical of the dark green banded amphibolites found in the area and might well itself be of metaigneous origin (?hornblendite). In addition to tremolite, the rocks locally contain small amounts of highly altered plagioclase and accessory rutile and iron ore, as well as alteration products.

The form of the corundum crystals and their enclosing envelopes is shown in fig. 1A. It can be seen that the corundum has been destroyed to varying degrees by alteration, as discussed below, until locally it disappears and a completely corundum-free envelope results. The envelopes are predominantly greenish, with thin outer rims of white material; sometimes these are thicker than the green layers, and occasionally a second green rim surrounds the white one. Microscopic and X-ray examination shows that they consist of two green layers and one or possibly two layers of white material. A typical example is shown in fig. 1B, in which the inner green layer is seen to consist of fibrous margarite (Ca brittle mica) and the outer one of fibrous chrysotile. The margarite has also formed along fractures, especially parallel to (0001), where it may reach 1 mm in thickness, penetrating the corundum, presumably at the latter's expense (Deer *et al.*, 1962*a*, p. 98); the total absence locally of corundum is thus considered to be due to complete alteration to margarite. The outer, narrow white rim consists of a mixture of chlorite, amphibole, and a clay mineral, with an irregular outer band of epidote. Finally, the region surrounding the envelopes, although not recognizable as a rim, contains a higher percentage of alteration material, especially kaolinite, than the remainder of the rock.

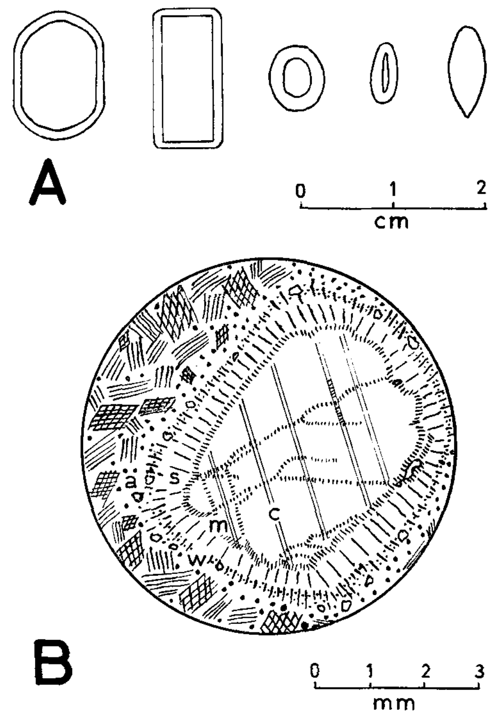

FIG. 1. A. Series showing large corundum crystals, with narrow green rims (left), grading into 'envelopes' with corundum totally absent (right). B. Tremolite amphibolite containing a lamellar-twinned corundum crystal (*c*). The inner green alteration rim (*m*) is of margarite, and the outer (*s*) of chrysotile serpentine. The surrounding narrow white rim (*w*) consists of chlorite, amphibole, and a clay mineral, with an irregular outer band of epidote, shown as discrete crystals. The region (*a*) contains a greater proportion of alteration products, especially kaolinite, than the remainder of the rock.

The envelopes were scanned by electron microprobe for unusual trace element concentrations. Sr and V are present in small amounts almost uniformly across the layers. On the other hand, Ba rises only within the inner margarite rim, on both sides of the central corundum, to a maximum of some 7000 ppm (*c.* 0·78% BaO). Relative to strontium, especially, this is an unusually high content for a margarite mica.

Assuming the corundum to have formed in the amphibolites as a result of desilication, as a porphyroblastic accessory mineral, the green envelopes must result from the inwards alteration of the corundum, associated with the outwards alteration (primarily serpentinization) of the adjacent amphibole. The following reaction is suggested as having taken place, in which chlorite and epidote are omitted from the products as being as easily produced as the more important secondary minerals:

$$\underset{\text{tremolite}}{3Ca_2Mg_5Si_8O_{22}(OH)_2} + \underset{\text{corundum}}{13Al_2O_3} + 15H_2O \longrightarrow$$

$$\underset{\text{margarite}}{3Ca_2Al_4Si_4Al_4O_{20}(OH)_4} + \underset{\text{serpentine}}{5Mg_3Si_2O_5(OH)_4} + \underset{\text{kaolinite}}{Al_2Si_2O_5(OH)_4}$$

A reverse process, in which corundum (later altering to margarite) grew within localized areas of serpentinization, due to a reaction in which, say, tremolite and, possibly, plagioclase yielded corundum, serpentine, and minor chlorite, kaolinite, and epidote, was also considered. However, there is little reason to suppose that the growth of corundum would be associated with serpentinization, even though it does remove the need to explain why serpentinization should accompany the alteration of corundum. The former explanation is therefore regarded as more probable, the corundum in some way acting as focal points for localized hydroxylation (which is unlikely to have occurred at random), resulting in both its own alteration and the serpentinization of the surrounding amphibole.

In rare cases, staurolite is found within the green envelopes instead of corundum. This mineral is also highly corroded and altered to margarite. There is no clearly demarcated system of rims as in the case of the corundum porphyroblasts, but the margarite region contains a small amount of a 7 Å clay mineral (? kaolinite or serpentine), and an irregular epidote band lies between the main alteration zone and the amphibole forming the bulk of the rock.

The presence of staurolite suggests a normal metasedimentary origin for a rock. In the present paragenesis, however, it is considered more probable that the physico-chemical conditions were locally such that staurolite formed as an alternative product of (less pronounced) desilication. Alternative explanations, which are discounted, are that either staurolite formed occasionally from corundum or, conversely, all the original porphyroblasts were of staurolite, nearly all of which subsequently altered, with further desilication, to corundum.

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On the plotting of binary and ternary diagrams by computer

A COMMON accessory to the larger computer installations is a Calcomp Plotter.[1] This equipment is programmed to accept a two-dimensional array as input, the output being a diagram on which the points are plotted relative to marked and scaled axes.

The library sub-routines with which the Plotter is programmed permit convenient labelling of the axes and a free selection of their length; any one of a variety of symbols may be chosen to portray the points in the plot. Division of the axes is made by the computer in accordance with the range of values present in the fed-in arrays; this is done in such a manner that the graph area determined by the axes is most economically utilized, subject to the use of rational divisions along the axes.

Whereas these arrangements are very convenient in that the minimum of attention need be paid for the production of a clearly labelled and accurately drawn graph, there are occasions when the user may wish to draw graphs that the standard routines do not permit. Examples from the broader field of mineralogy are presented for which new sub-routines have been written in Fortran IV to remove such restrictions. Familiarity with the use of standard Calcomp plotting procedure must be assumed.

Independent scaling. The mineralogist may wish to plot points according to a scaling of his own. For example, two separate plots may be required using say basic rocks and acid rocks on FeO–MgO diagrams. For purposes of comparison the separate graphs would be drawn to the same scale, irrespective of the fact that in the acid-rock diagram much of the field will remain empty. A new sub-routine to permit independent scaling, ADJUST, has been written; it is used in place of SCALE. In the absence of SCALE the LINE routine cannot be used: the difficulty is overcome by the use of SYMBOL in its place.

[1] A product of California Computer Products, Inc., 305 Muller, Anaheim, California 92803, U.S.A.