

DISTRIBUTION AND BEHAVIOUR OF THE TRACE ELEMENTS IN THE
ROCKS OF THE SAUSAR SERIES AROUND DONGARI—CHORBAOLI AREA.
DISTRICT NAGPUR, MAHARASHTRA

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Introduction: The rocks exposed in the area belong to Sausar series (Archaeans). The area is included in Survey of India toposheet No. 55 0/6 and 55 0/7. The lithologic units are mainly comprised of calcareous rocks, calc-silicates, quartzo-feldspathic rocks and amphibolites. The calcareous metasediments comprise calcitic and dolomitic marbles. The calc-silicates and marbles grade into one another and are not mappable separately. The amphibolites occur as bands in both marbles and calc-silicates and their margins with the host rocks are not sharp and cannot be demarcated. The quartzo-feldspathic rocks have been so named as they contain high percentage of feldspar and quartz.

In the present paper an attempt has been made to give the distribution pattern of the trace elements in amphibolites, calcareous rocks, calc-silicates and quartzo-feldspathic rocks. The behaviour of trace elements under different lithological and environmental controls and the relationship between the major and trace elements in these rocks have been discussed.

Distribution and behaviour of trace elements: Strontium: It ranges from 1000 to 5000 ppm, being chiefly concentrated in amphibolites followed by calcareous ones. The quartzo-feldspathic rocks are relatively poor in this element. Among the amphibolites both calcite as well as alkali rich types are most abundant in this element. In the amphibolites strontium has equal latitude to be present either in the plagioclase or the potash feldspar. However a comparison of trace and major element data shows that in microcline bearing rocks, strontium is less abundant than in plagioclases. Obviously in the present environment, in the amphibolites, strontium has followed calcium rather than potassium. In the case of calcareous rocks also a similar relationship between these two elements, namely calcium and strontium exists; but it is significant to note that in such cases the strontium content is related to the plagioclases rather than calcite as observed from the mode and trace element data of the calcareous rocks. In case of calc-silicates this relationship is excellently revealed in diopside-plagioclase-quartz and diopside-quartz-plagioclase associations; but in the case of diopside-garnet-quartz association, which is devoid of plagioclase, strontium does follow the potash feldspars. Almost similar relationship as pointed out above exists between potassium and strontium in quartzo-feldspathic rocks. It may be summarised that the entry of strontium is chiefly governed by lattice considerations rather than potassium or calcium content of the rocks.

Barium: In the present instance barium like strontium is most abundant in amphibolites, chiefly those which are rich in lime and alkalies. In the calcareous rocks, it is more or less evenly distributed while in calc-silicates it shows a progressive increase with increase in metamorphism. It may be mentioned that Engel and Engel (1951) have stressed the utility of barium in distinguishing ortho-amphibolites from the para-ones. With meagre results as in the present instance, no such generalisation can be given but the analytical data of these rocks together with the distribution pattern of trace elements do point out to some extent that barium bears relationship to stage of metamorphism. As regards the choice of barium between calcium and potassium,

same theory holds good as for strontium, that is, the lattice considerations are the prime factors to decide which of the two major elements mentioned above replace or be replaced by barium.

Tungsten: In the case of the rocks of the present area tungsten is more in the amphibolites than in calcareous and calc-silicate rocks which bear even quantities of this element. Such a monotonous behaviour of this element in amphibolites seems to be related to the original W-content of the sediments. In the amphibolites tungsten is more in quartz-rich and alkali-rich rocks; surprisingly the iron-rich amphibolites contain this element only in traces. When the behaviour of this element is seen in relation to Si, Al, Fe⁺³ it becomes apparent that tungsten follows the complex silicate structure rather than that of Al⁺³ or Fe⁺³. This has an important relationship with the subsequent chemical activity during metamorphism of the amphibolites; and if it were so, the slightly higher tungsten contents of these rocks become explicable.

Vanadium: It is conspicuously high in amphibolites, ranging between 250 to 300 ppm. From quartzo-feldspathic rocks it is altogether absent while in the calcareous rocks and calc-silicates it shows more or less an even distribution. Wager and Mitchell (1951) have shown that vanadium bears close affinity towards Fe⁺³ ions. In the present instance, however, in such relationship is visible in the amphibolites. Further, the vanadium content of the calcareous and calc-silicate rocks where Fe⁺³ is poorer, is quite high. There seems no apparent reason for the latter type of behaviour of this element, except that during subsequent metamorphic activity this element has been added up. In this connection the close association of the calcareous and calc-silicate rocks with the amphibolites cannot be ignored.

Molybdenum: In its distribution pattern, except for some of the amphibolites where its amount reaches 50 ppm, it occurs in the neighbourhood of 15 to 20 ppm. In the calcareous rocks, however, it is mostly absent. It seems that the quantity of molybdenum is dependent on the availability of sulphur in the environment. Activities promoting the latter cannot easily be envisaged during medium or high grade metamorphism except where anatexis has already set in. Under these circumstances the behaviour of this element cannot be fully explained. Suffice it to mention that the even pattern of distribution of Mo has obviously something to do with a late stage introduction of this element in the present set up.

Yttrium: In general it is more in calc-silicates, though in amphibolites the value of this element in individual rocks goes to 800 ppm. In other words, the average yttrium content of the calc-silicates is higher than in the amphibolites. In calcareous and quartzo-feldspathic rocks it ranges between 100 to 300 ppm. Singh (1966) has reported that yttrium is maximum in the quartzo-feldspathic rocks of his area. He has also shown that the ortho-amphibolites of his area are equally abundant in yttrium. The present results do not substantiate such an hypothesis; on the other hand, the calc-silicate rocks, on an average contain more yttrium. It is known that yttrium usually follows calcium in suitable structures due to its closer ionic radius to calcium. It therefore seems that the geochemical behaviour of yttrium has been controlled by calcium. However, it must be mentioned here that only such calcium which is contained in the pyroxene, (diopside), is capable of accommodating this element than the calcium of the calcites.

Chromium: The distribution pattern of chromium shows that it is richest in calc-silicates and poorest in calcareous rocks. In amphibolites it ranges between 100 to 350 ppm. The quartzo-feldspathic rocks are highly depleted in this element. The

abundance of this element in calc-silicates cannot be explained unless it is supposed that the latter have been derived from originally mafic rocks. The close vicinity of amphibolites with calc-silicates would have explained to some extent the enrichment of chromium in calc-silicates, had not the chromium contents of amphibolites themselves been lower. When the relationship of chromium with Fe^{+3} , is seen it is noted that in the earlier stages of metamorphism (lower temperature) chromium has followed Fe^{+3} . The same however, is not true in highly metamorphosed rocks formed at elevated temperature. In the amphibolites also it is noted that the two elements show complementary character.

Nickel: It is maximum in amphibolites (100 to 300 ppm) and minimum in quartzo-feldspathic rocks. In the calc-silicates its limits are 30 to 300 ppm; in other words, even nickel in some of these is on a par with its amount in amphibolites. Nickel in calcareous rocks is poorly distributed. When the relationship between nickel and magnesium is observed it is seen that nickel strictly follows the latter element. Among the minerals which may accommodate appreciable amount of this metal are hornblende in the case of amphibolites and pyroxenes in the case of calc-silicate rocks. In calcareous rocks nickel may be related to subsequent metamorphic activities.

Cobalt: Cobalt like nickel is maximum in the amphibolites and minimum in quartzo-feldspathic rocks; surprisingly the iron-rich amphibolites are depleted in it. In the calcareous rocks its amount is conspicuously high when compared to rocks from other areas. The calc-silicates contain 150-200 ppm. of cobalt. Among the corresponding major elements Mg and Fe^{+2} , in the present instance, cobalt seems to have followed Fe^{+2} more closely while it shows complimentary behaviour with respect to MgO. Among the minerals, it is contained more in hornblendes and pyroxenes.

Copper: In the present instance except for the calc-silicates and few amphibolites, its amount remains more or less uniform. It may be noted here that in the amphibolites copper is contained chiefly in plagioclases and less in hornblendes. In the calc-silicates the reverse holds good, it is contained in the ferromagnesian minerals rather than plagioclases.

Lithium: The distribution pattern of lithium shows that it is maximum (up to 200 ppm.) in alkali rich amphibolites. In other types it occurs in slightly lesser quantities. Next to amphibolites in their lithium content are the calc-silicates followed by the quartzo-feldspathic and calcareous rocks. From some of the latter it is altogether absent so that the average Li content of the calcareous rocks is negligibly low. A comparison of lithium values with those of magnesium in the amphibolites shows that it has progressively substituted for magnesium in calcite-rich rocks while in the others it follows magnesium. In the calc-silicates lithium strictly follows magnesium.

Gallium: It shows a poor distribution in amphibolites but in the calc-silicates and quartzo-feldspathic rocks its amount is relatively high (up to 200 ppm.). In the calcareous rocks it is practically absent.

Indium: It is maximum in the amphibolites while minimum in the quartzo-feldspathic rocks. In the calcareous rocks and calc-silicates, it occurs in more or less similar amount.

Beryllium: It occurs in very small amounts in most of these rocks, being maximum in quartzo-feldspathic ones. Surprisingly even the amphibolites contain this element.

Summary and conclusion: From the above distribution patterns, the trace elements occurring in the rocks of the present area may be grouped under the following categories:

- (a) Trace elements which are abundant in the amphibolites.
- (b) Those which, though characteristic of the amphibolites, are similarly distributed in some of the other rocks.
- (c) Those which are either constant or show an erratic distribution.

It has been pointed out that Sr, Ba, W, Li, In, Co, Ni and V show highest abundance in amphibolites. Barium is highest in quartzo-feldspathic rocks. Gallium has poor distribution in amphibolites and is relatively very high in calc-silicates and quartzo-feldspathic rocks. It has been noticed that the entry of strontium and barium is chiefly governed by lattice considerations rather than the potassium and calcium contents of the rocks. In the amphibolites, when the behaviour of tungsten is seen in relation to Si, Al, and Fe^{+3} , it becomes apparent that the tungsten follows complex silicate structure rather than Al^{+3} or Fe^{+3} . The behaviour of vanadium is suggestive of a close relationship of calcareous and calc-silicate rocks with the amphibolites.

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