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Geology of Sri Lanka in relation to Plate Tectonics

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Abstract : The crystallines of the Island of Sri Lanka is divided into Highland series and Vijayan series and the contact between these two series is a possible Paleo plate boundary. The geological evidence supporting this interpretation includes :—

The presence of paired metamorphic belts—the granulite facies and the amphibolite facies.

The presence of basic and ultrabasic rocks of probable igneous origin closer to the Highland-Vijayan contact.

The copper-magnetite-apatite body and its related rocks. It is possible that mineralisation has taken place at the boundary between the two main rock groups.

The hot springs of Sri Lanka mainly confined to Vijayan series and are mostly along the contact.

The Submarine Canyon with wall heights 1,350 meters off the coast of Trincomalee contiguous with the Highland-Vijayan contact.

The interpretation is that the boundary between the Highland-Vijayan series was an old subduction zone; where the two plates were moving together. Active volcanism continuous subduction and upliftment have caused the present day Highland series. The rocks of the Highland series comprises of quartzites, crystalline limestones, garnetiferous granulites and charnockites. The volcanic rocks are not present today, as they have been eroded away. Both groups are intensely metamorphosed and metasomatised. The Highland series was metamorphosed to the granulite facies and the Vijayan series to the almandine-amphibolite facies.

1. Introduction and General Geology of Sri Lanka

Sri Lanka though an island today, is an integral portion of the carnatic gnessic terrain of the Deccan Peninsula of India only recently severed from the mainland. An attempt has been made in this paper to interpret the Geology of Sri Lanka in terms of plate tectonics.

The major geological divisions of Sri Lanka are given by (Figure 1).[3] The greater part of the country is underlain by crystalline rocks of Pre-Cambrian age; which are divided into two groups on the basis of metamorphic rank and age. The Highland Series metamorphosed to granulite facies[6] which occupies the central part of Sri Lanka consisting of a succession of gneisses, garnet-sillimanite-graphite-gneisses, quartzites and marbles together with charnockites. Migmatites and granite gneisses are less developed in the Highland Series.

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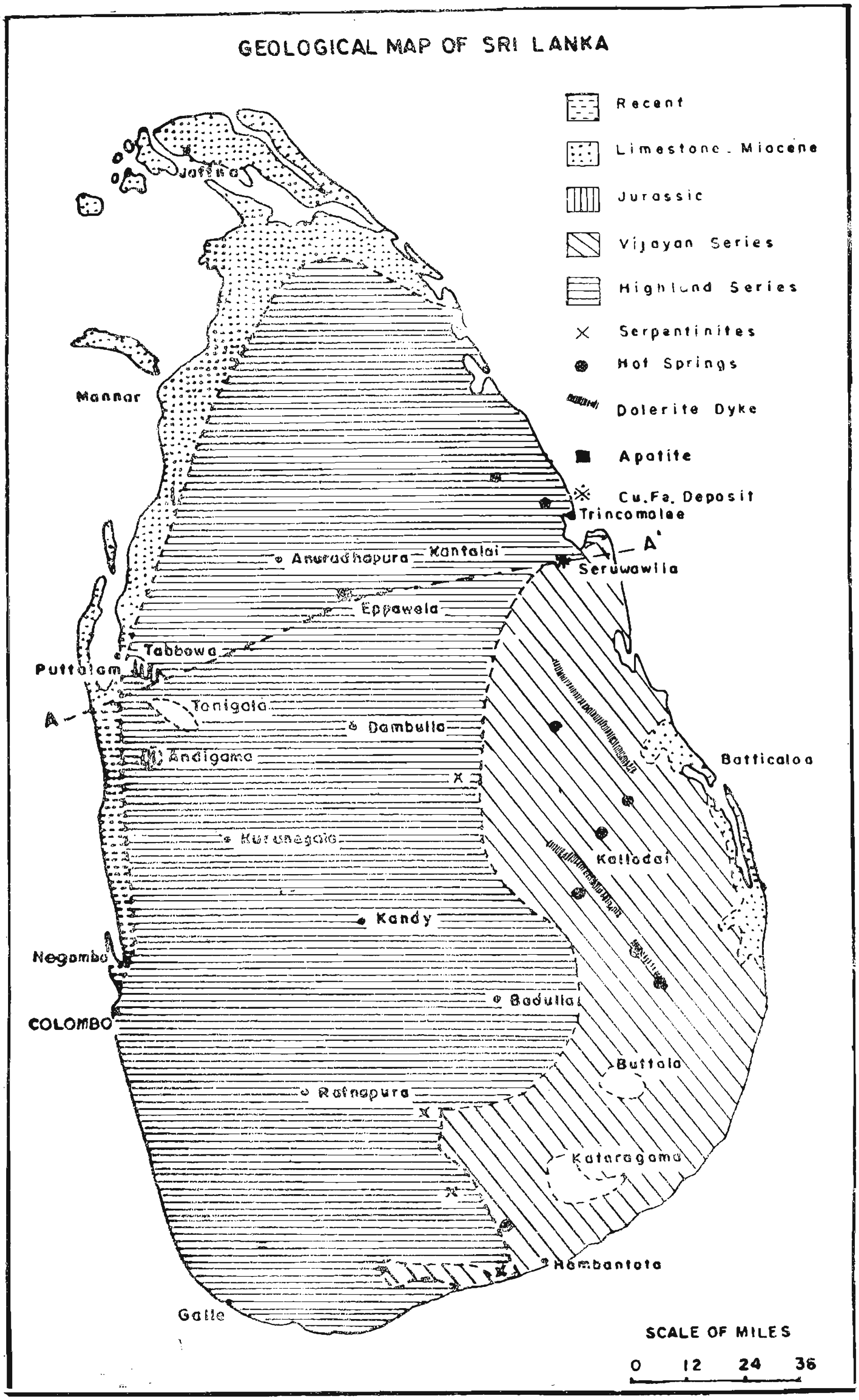


Figure 1. Geological Map — Sri Lanka

The Vijayan series metamorphosed to the amphibolite facies[6] which consist mainly of microcline-biotite and hornblends biotite-gneisses, granites and granite gneisses, and occupies the eastern and south-eastern Lowlands.

Mesozoic rocks, mainly sandstones, shales and siltstones of Upper Gondwana age (Wayland, 1925) are preserved in faulted basins at Tabbowa and Andigama near Puttalam. In the north-western part of the country the dominant rock is the sedimentary limestone which underlies the whole of Jaffna Peninsula and the surrounding Islands. This limestone belt extends southwards along the west coast of the Island as a gradually narrowing belt.

2. Previous Work

There is no direct evidence to show the origin of the Highland series Adams[1] considered the peneplain which they represent, to be produced by ordinary denudation of dip slopes. Wadia (1945) impressed by the "Stupendous Mural Scarps" emphasised the horst like nature of the central Sri Lanka massif and suggested block uplift of the Highlands through powerful dislocations and block faults of the normal type. King[11] points out that direct faulting has not been forthcoming and the mighty rock faces are seemingly true "Erosion Scarps". More recently Vithanage (1972) postulated that the regional morphotectonic and morphological features can be explained by normal erosion acting on the Precambrian terrain which has been subjected to prolonged differential warping along a broad SSW-ENE zone. The predominant deformations were by series of vertical differential uplifts with a culminating phase around Jurassic (Gondwana and Miocene early to end of Tertiary). Hatherton *et al*[7] predicts that the central Highlands appear to be completely uncompensated isostatically. The largest scale anomaly in the island runs along the western part of the Vijayan series and parallel to its junction with Highland series (see Figure 2).

3. Geological Processes at Plate Boundaries

According to the plate tectonic hypothesis, the outer layer of the earth consists of lithosphere, 80 to 100 km thick divided into a number of rigid plates moving relatively to each other over a plastic asthenosphere. There are twelve major plates and thirty minor plates recognised at present. Volcanism, mountain building, and mineralization are concentrated at the boundaries of these plates. Plate boundaries are three types, constructive, destructive and conservative. At constructive plate boundaries new lithosphere is consisting of a layer of oceanic crust overlying the

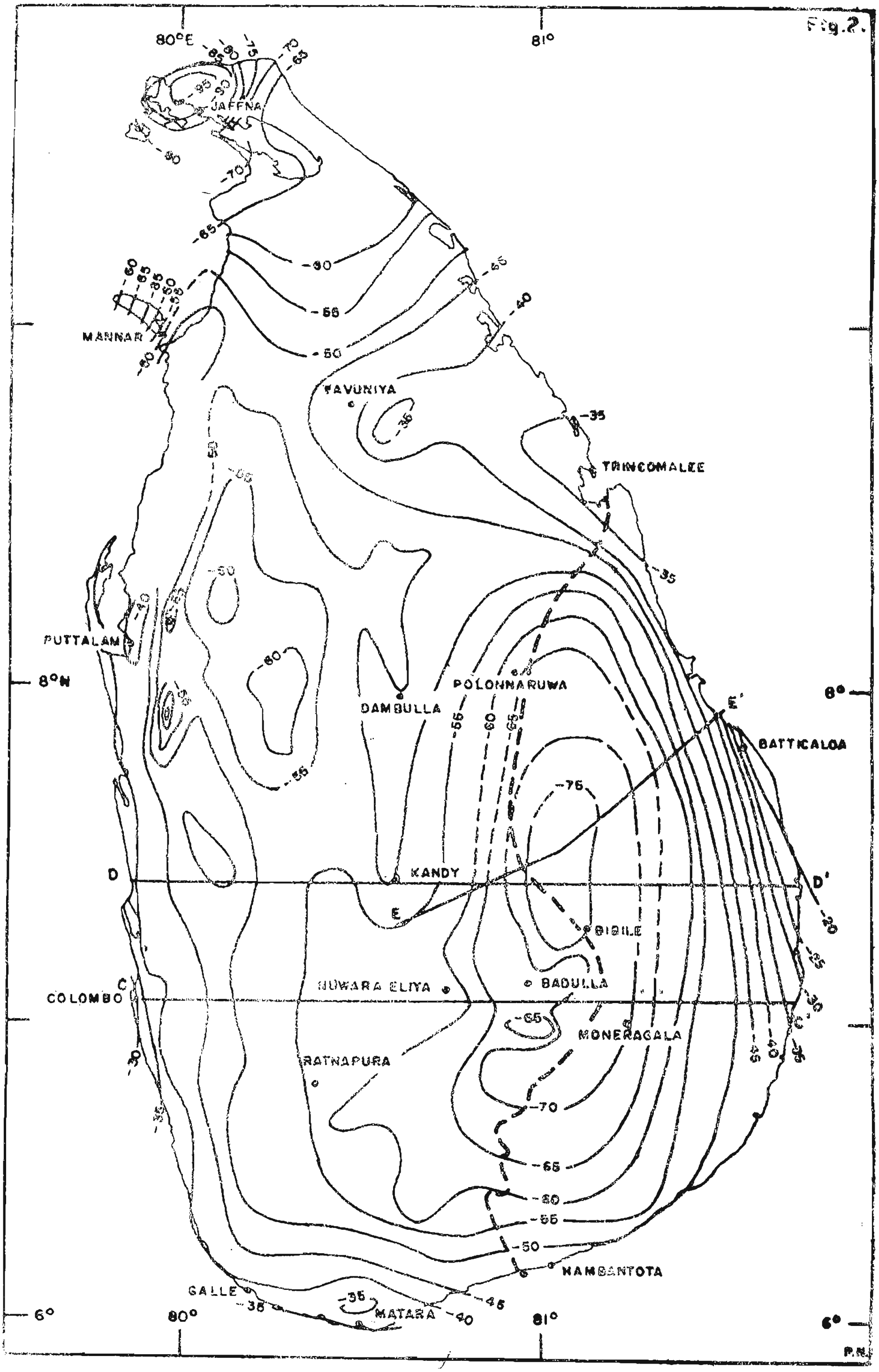


Figure 2. Hybrid gravity anomaly map, Sri Lanka. (After Hatherton *et al*)

upper mantle ,and it is created either continuously or intermittently at the rate of spreading of about 10 cm per year along the axis of an oceanic spreading ridge system. At constructive plate boundaries the plates move away from each other (Figure 3). At destructive plate boundaries the plates move opposite to each other (Figure 4) and the collision result due to continuous subduction of the oceanic-crust, for example the collision of Indian plate with the Asian plate in the Tertiary following subduction and closure of Tethys ocean. At conservative plate boundaries the plates move parallel to each other along a transform fault. Transform faults are linked with ridges trench systems and at times large faults on lands, for example the San Andras fault in the U.S.A. and Alpine fault in the South Island of New Zealand. The spreading ridges, trenches associated with subduction zones and transform faults form a continuous linked network around the Earth Surface.

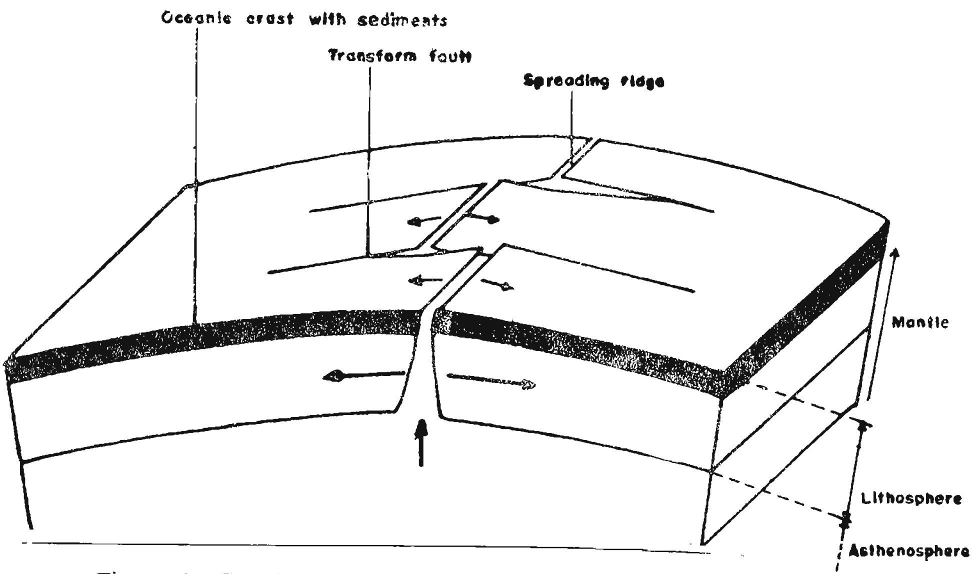


Figure 3. CONSTRUCTIVE PLATE BOUNDARY

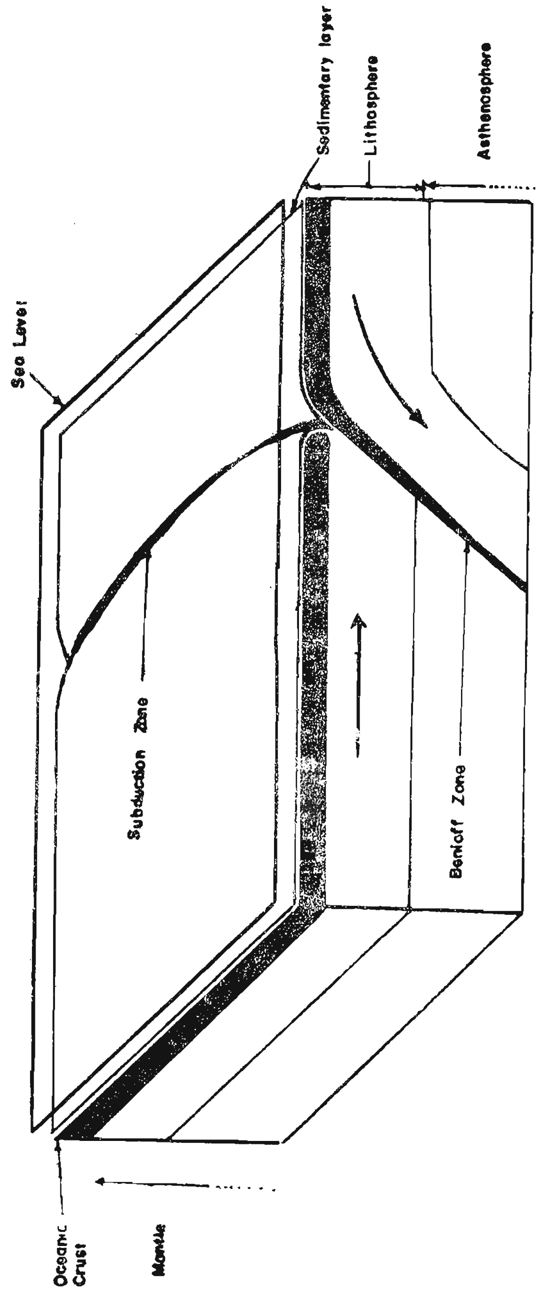


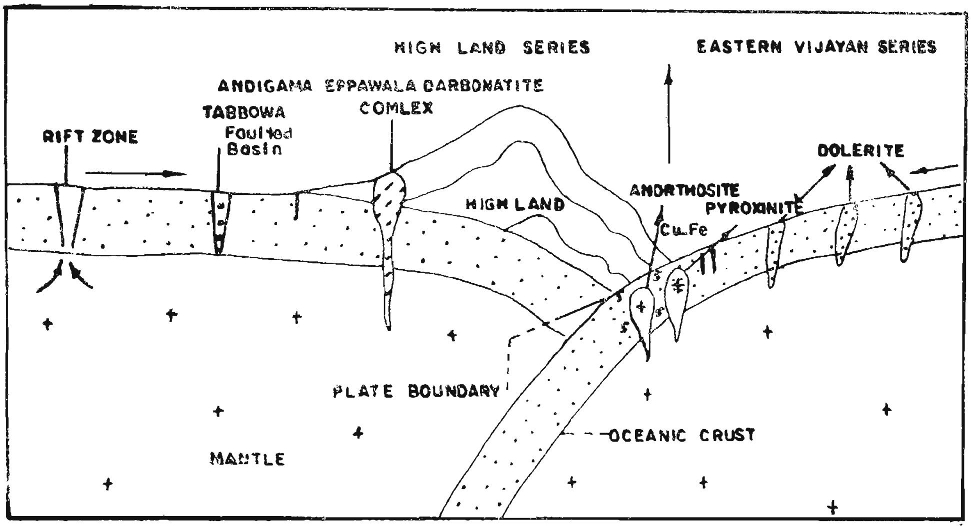
Figure 4. Destructive plate boundary

4. Some Possible Evidence of the Plate Boundary

In Sri Lanka the boundary between the Highland and Vijayan series can be of the destructive type. The outerparts of the Eastern and Western Vijayan crust can be considered as two micro plates, passively moving about on a plastic asthenosphere (the upper mantle) (Figure 5). The geological and the tectonic setting of the Highland series and the Vijayan series is a clear indication of a possible plate boundary. The geological evolution of Sri Lanka began with a deposition of thick sediments in a Pre-Cambrian geosyncline.[3] The rocks of the Highland series were laid under sedimentary conditions bringing material from the Eastern and Western limbs of the geosyncline. The Highland series is an elongated belt extend from SSW to NNE of the Island varying its strike and direction. The rocks are mainly quartzites, quartzschists, crystalline limestones, calc granulite gneisses, and quartz-felspar-garnet-granulite gneisses. The quartzites are metamorphosed sandstones found in all parts of the Highland series belt. Crystalline limestones and calc granulites are metamorphosed sedimentary limestones. Carbonates of calcium and magnesium are the two main constituents of these rocks. The presence of silicate minerals very often in the crystalline limestone band suggest that quiet seas in which calcarious sediments were laid down from time to time inundated with sand and clay, were perhaps brought down by flood waters.[3] The calc granulites are very impure calcarious sandstone formed by the metamorphism of calcarious muds, quartz-felspar-garnet-granulite gneisses are metamorphosed sandy clays and clayey sands.

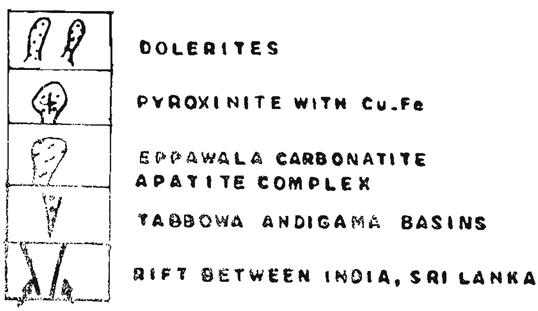
The Vijayan series consist of mainly granites, granite gneisses, augen gneisses and migmatites. The minerals present are quartz, microcline, plagioclase, biotite and hornblende. These minerals occur with monotonous regularity in the Vijayan rocks. These rocks extend as isolated knob like masses and in some places as ring-structures in the Yala and Panama 1 in sheets.[12] Minerals like silimanite, graphite, cordierite hypersthene and garnet so typical of the Highland series are seldom seen in the Vijayan series.[1] The Buttala and Kataragama complexes may well represent, 'Klippen' severed from the main Highland series block.[7] In comparison with the rocks of the Vijayan series the rocks of the Highland series are well bedded, banded and run continuously for miles along the strike with little variation and hardly any dislocation. The Vijayan rocks are seldom uniform. It is seen that these two groups are completely different in their mode of origin. It can be considered that these Highland series (the granulite facies) and Vijayan series (the amphibolite facies) are paired metamorphic belts with the relics eroded away.

GEOLOGICAL SECTION OF SRI LANKA - ALONG LINE A - A'



SCALE 1" = 36.5 Killometres

(Figure 5)



5. Basic and Ultrabasic Rocks

Basic and ultrabasic rocks are located along the Highland series and Vijayan series boundary. The basic rocks are fine grained quartz dolerites and albite dolerites ; a very few medium grained basic rocks are also observed at a number of places in the Vijayan series. The dolerites and the ultrabasic rocks are shown in the Figure 1. Petrological and mineralogical studies of the basic rocks show two groups with diagnostic mineral assemblages as given below of which the first is dominant ;

(*a*) apatite ilmenite $\pm$ olivine clinopyroxene and plagioclase

(*b*) ilmenite clinopyroxene and plagioclase

Similar type of mineral assemblages are found in the basic and ultrabasic rock suite in the South West of England.[4] The greenstone belt in the South West of England are basic in character with quartz dolerites, albite dolerites and spilite dolerites, and the ultrabasic rocks are very few in this area and are serpentinised. It may be possible that the basic and ultrabasic rocks of the Vijayan series are akin to the rocks of the greenstone belt of the South West of England.

The most important occurrence is the serpentinite body at Udawalawe surrounded by migmatitic gneisses and crystalline limestone and is located in the South East quadrant of Sri Lanka near the Highland Vijayan boundary.[10] Katz considered that this ultramafic belt is an ancient Pre-cambrian suture of two plates.

The presence of serpentinite peridotite and dolerites is strong evidence for a tectonic setting, the gravity evidence is consistent with a thrust contact between the two major rock groups. The low density at the boundary suggest that there was down-warping and this was due to the continuous subduction of the Eastern Vijayan crust.

6. Copper-Magnetite Body and its Related Rocks

There were a number of attempts to relate ore deposit genesis to plate tectonics. The distribution and origin of some classes of mineral deposits have recently been interpreted in terms of the plate tectonics hypothesis, (Mitchell and Garson, 1976). In Sri Lanka an occurrence of a body of copper-magnetite was discovered in 1971 at the Highland Vijayan boundary. The copper magnetite body is located in the Trincomalee district and is about 30 miles east of Kantalai, at Seruwawila (Figure 1) and is in the North Eastern quadrant of Sri Lanka. Detailed mineralogical and petrological studies have indicated that copper mineralization is confined to a pyroxinite which is associated with granites. The constituent minerals of the pyroxinite detected by microscopic studies are tremolite, diopside, augite, scapolite, apatite, chalcopyrite and magnetite. Basic and ultra-basic rocks and anorthosite rocks are found to be erupted closer to the magnetite deposit prospect. The copper magnetite deposit is found to be associated with cherty rocks. The presence of chert in the deposit suggests that sea water was in contact with erupted lavas and became enriched in silica which would have been deposited as the temperature fell. The apatite in the magnetite body suggests that gaseous emanations have taken place in the formation of the ore body.

Two occurrences of anorthosite intrusions are exposed closer to the copper magnetite apatite body and is located at the 3rd milestone on the Seruwila-Toppur road. The rock is highly coarse-grained and composed mainly of plagioclase laths with scattered grains of garnet. This is the first recorded occurrence of anorthosites in Sri Lanka, and the most interesting fact is that the location is almost at the contact of the mineralized area with the country rocks to the West. The detailed petrological and mineralogical studies carried out indicate that the plagioclases contained are andesine and labrodorite with Na_2O content 6.15%. The anorthosite at Seruwila may not represent a deep crustal or upper mantle material but a reworked material intruded along a faulted contact zone.[9]

About 60 km to the West of the Highland Vijayan boundary west of the magnetite deposit is the carbonatite (apatite) complex. This is located in the North Central province of Sri Lanka and falls within the Western Vijayan series.[2] The closer examination of the lithology of the carbonatite area shows an association of rocks akin to the Highland series. Geochemical study of the carbonatite complex concludes that the limestones are of igneous origin that has equilibrated from a carbonatite magma. The geochemistry of the Eppawela apatite is similar to the East African type.[8] In most of the East African carbonatite the mineralization has taken place at the intra continental rift zone plate boundaries, (Mitchell and Garson 1976). The carbonatite at Eppawela may have resulted due to subduction of the Eastern Vijayan oceanic crust and the partial melting of the crust at depth, deeper in the Benioff zone have resulted a carbonatite magma which has later intruded into the meta sediments (The Highland Series).

7. Mineral and Thermal Waters of Sri Lanka

Mineral and thermal water of Sri Lanka are described by J. P. R. Fonseka *et al.*[5] All known springs occur in the coastal plain of the East and South east section of the island where also dolerite dykes are best exposed (see Figure 1). At present, there are nine thermal springs ; six of the nine thermal springs are located in the East and South Eastern coastal plain of the island which is underlain by genisses of the Vijayan series. The other three namely Mahapellessa, Kanniyai and Rankihiriya are in the area underlain by Highland series. All the springs seep out invariably at ground level, without any appreciable head, from hollows or sandy bottoms of ponds or pools. A few issue from the fissures in the bedrock.

The origin of the mineral and thermal water is probably due to deeply circulating ground water. The most interesting feature is that all these hot springs confine to the Eastern and South Eastern sections of the island.

Geological Evolution of Sri Lanka

It is now realized that collision is probably the most important single cause of mountain building and orogeny and ancient collision belts and suture zones have been recognized in a number of orogenic belts Precambrian to Pliocene in age Many papers have been written on mineralization at plate boundaries and the hypothesis is hown to be useful in explaining the origin of the host rocks of the ore bodies.

Sri Lanka Highland series was once a minor orogenic belt. This was an elongated zone extending from S.S.W. to N.N.E varying in strike and direction. The thickness of the sediments are much thicker compared with the Eastern Vijayan rocks. The elongated zone may have started as a geosyncline, accumulating sediments during Precambrian time. The Highland rocks have formed due to the continuous subduction of the Vijayan oceanic crust (Figure 5) and subsequent series of differential upliftment with a culminating phase around Jurassic to end of Tertiary. The strata were eventually folded and crumpled, faulted and overthrust and more or less intensely metamorphosed at different stages of historic evolution.

The Seruwila copper magnetite apatite body is another feature that shows mineralization has taken place in a plate boundary.

The presence of chert and apatite in the copper magnetite body shows that lavas have been contaminated with sea water and gaseous emanations had taken place.

The basic and ultrabasic rocks, anorthosites, granitic ring structures in the Vijayan series shows that there was active volcanism.

The submarine canyon with wall heights of 1,350 meters at Trincomalee and also the hot springs are contiguous with the Highland-Vijayan contact. The Eppawela apatite carbonatite complex is also a result of the converging plates, and the partial melting due to continuous subduction have resulted in carbonatite lavas, although there is no geochemical evidence.

The Andigama Tabbowa Gondwana basins are the tensional cracks formed as a result of the movement of the two plates. The rift valley between India and Sri Lanka (the cauvery basin) is also a result of the movement of the converging plates.

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