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Chitar-Sendra Ophiolite, NW India: Suprasubduction Zone Setting For The Oldest Basin Part of Pan-African And Brasiliano Ophiolite.

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Abstract

Ophiolites have been hypothesised to have formed in a wide variety of tectonic settings due to the astonishing diversity of their interior structures, pseudo-stratigraphy, and chemical signatures. There were several Wilson cycle phases in the history of ancient oceans, and throughout each one, collisional or accretive orogenic processes absorbed mafic-ultramafic assemblages and the sedimentary and metamorphic rock groups they were associated with onto continental borders. Oceanic crust may be generated in subduction rollback cycles near the end of basins before terminal continental impacts, as seen with the ophiolites in orogenic belts. The Chitar-Sendra ophiolite in northwest India formed over a subduction zone, as shown by its lithology and geochemistry. Central Asia (including the Agardagh Tes-Chem, Songshugou, and Jiangxi ophiolites), the Lesser Caucasus (the Trans-caucasian massif), and central and eastern Europe all have ophiolites that date back to the Late Proterozoic (860 Ma) (the Cadomian belts in northwest France and the Rhodope massif, respectively). Ocean basins opened, widened, and closed throughout the Wilson cycle, as recorded in Neoproterozoic ophiolites; this shows that contemporary plate tectonic processes were well established by 1.0 Ga. As a result of subduction, the older oceanic lithosphere at the mid-ocean ridge basalt (MORB) was destroyed, while only a minor quantity of new oceanic lithosphere was created above the subduction zone. When trying to piece together how the early basin of the Pan-African and Brasiliano ophiolite formed, the Chitar-Sendra ophiolite is a must-have piece of the puzzle. The biggest oceanic domain at the time was closed off when the Proterozoic oceanic crust, juvenile island arcs, and oceanic plateaux of the Pan-African and Brasiliano Ophiolite united during the creation of collisional and accretionary type orogens.

Keywords: Pan-African ophiolite, suprasubduction, Chitar-Sendra Ophiolite, NW India, oldest Ocean basin.

Introduction

A new ocean basin may be the defining characteristic of the Aravalli orogeny (1,800 Ma). The Columbia supercontinent formed in the Aravalli rift basin between 2500 and 1800 Ma. The eastern Bundelkhand craton and the western Marwar craton were separated by the emergence of the Aravalli oceanic basin in the Paleoproterozoic epoch. The Aravalli Supergroup was formed by a combination of factors, including sedimentation, fundamental magmatism, and the slow subsidence of the floor of the Aravalli Basin. It didn't take long for the eastern Bundelkhand craton to subduct under the western Marwar craton when rifting ceased. Subduction zone steepening and island arc formation are direct results of the ongoing craton collision. The Aravalli Supergroup was uplifted at about 1800 Ma after a lengthy period of collision. The thrust fault steepened considerably during the last stage of convergence, leading to suturing of the colliding blocks. The Great Boundary Fault divides the suture zone from the rest of the planet. These ophiolites date back to the Late Proterozoic (860 Ma) and can only be found in South America, Africa, and Arabia. Included are the Cadomian belts in northwest France and the Rhodope massif in central and eastern Europe (Figure-1), as well as the Agardagh Tes-Chem in Central Asia, the Songshugou in China, and the Jiangxi ophiolite in eastern China, among other tectonic features (POS). These ophiolites separated the eastern Bundelkhand craton from the western Marwar craton during the Paleoproterozoic, when the Aravalli oceanic basin deepened. The ophiolites of the Phulad Ophiolite Suite are useful for reconstructing the tectonic conditions that prevailed during the collision of the eastern Bundelkhand craton and the western Marwar craton and the closure of the earliest ocean basin part of the Pan-African and Brasiliano Ophiolite (POS).

Regional and local Geology of the study area

The Aravalli Range separates the northern and western halves of Rajasthan. Approximately 700 kilometres long, it connects Delhi and Champaner and is bounded to the east by the Great Boundary Fault (GBF) and to the west by the Western Margin Fault. Its width varies from from 10 km to well over 50 km. West to east, the Phulad Ductile Shear Zone is a large fissure in the Earth's crust (Ghosh et al., 1999). To wit: (Gupta et al., 1980). The Barotiya-Sendra deposits may be linked to a rich sequence of mafic and ultramafic rocks that extends all the way along SDFB. Researchers gave these rocks the name "Phulad Ophiolite Suite" after a local mountain range (Gupta et al., 1980). Ultramafic rocks like those found in the Phulad Ophiolite Suite demonstrate that the primordial seabed was maintained from the start (POS). Across more than 300 kilometres, from Ajmer in the north to Palanpur in the south, a linear band of exposed rocks belonging to the Phulad Ophiolite Suite can be seen. The breadth of the exposed portion varies from 20 to 50 kilometres, and the rocks are interrupted by granite intrusions (POS). The Paleoproterozoic Aravalli Supergroup (2500-2000 Ma) and the Mesoproterozoic Delhi Fold Belt (1600 Ma) are the two most prominent volcanic-sedimentary bands that make up the Aravalli Mountains (1700-1500 Ma). The Banded Gneissic Complex (BGC), a suite of gneisses and schists that initially emerged about 3300 Ma ago, may be the origin of these fold belts (Gopalan et al., 1990).Heron (1953), Gupta et al. (1997), Roy (1988), Roy and Jakhar (2002), and Roy and Purohit (2005) all provide useful context about the local stratigraphy (2005). (2005). (2018). Delhi Fold Belt, located to the west of the Aravalli Mountains, is split into the North Delhi Fold Belt (NDFB) and the South Delhi Fold Belt (SDFB) based on the ages of the granite found there (Chaudhary et al., 1984; Deb and Sarkar, 1990). The two fold belts are divided by the Archean gneissic landscape close to Ajmer (Sinha-Roy et al., 1995). The Alwar Group, which is rich in coarse clastics and arenite, may be found in the lower belt, while the Ajabgarh Group, which is rich in pelite, may be located in the higher belt (Heron, 1953). SDFB has rechristened Alwar as Gogunda and Ajabgarh as Kumbalgarh (Gupta et al., 1997). According to Gupta et alresearch, .'s the Barotiya-Sendra (conglomerate, sub-arkose, calcic gneiss, and pelitic schist), Rajgarh (pelitic and psammitic rocks), and Bhim formations make up the Kumbalgarh Group (1991). Sediments composed of pelite and carbonate in the areas of Chanwarli, Ranakpur, Desuri, Phulad, Bar, and farther west to beawar and Ajmer are under danger owing to a fault on the western side of the region. Possible westernmost extent of the Aravalli Mountains. Examining the Chitar-Sendra ophiolite began at a more inland location east of Bar and continued all the way to the city centres of Sendra and Chitar. The author mapped the area's geology and created a regional stratigraphy for this book (Figure -2). A lot of the people in the Chitar-Sendra neighbourhood live in the basements of bars in Bar Village since it's cheaper than renting an apartment. Perhaps, like the Bar Conglomerate, a phyllite litho unit can be found here. A form of the mineral phyllite, ophiolite is distinct. Less frequent than the ophiolites of the other two divisions, the ophiolites of the phyllite unit consist of minerals including quartz, boninite, carbonatites, pyroxenite, clinopyroxenite, andesite, quartz diorites, and komatiite. The series also includes alluvium from nearby rivers and sand thrown in by the wind (Table-1).

Stratigraphic Succession at Chitar- Sendra Area

1. Most notably, the Sandra Formations in the lower portion of the Delhi Super Group have a phyllite litho unit. Phyllite has a fairly regular grain size distribution and an aphanitic crystal structure. This gneiss ranges from schist to slate in composition. Lower elevations are more typical for phyllite, and it is typically profoundly dissected by local drainages of lower rank. Dykes and dykelets with thicknesses between 10 and 30 centimetres include komatiite, komatiite basalt, and boninite. Studies are being conducted to determine whether or if the elongations in the Chitar and Sendra region are reflective of the schistosity of the host phyllite and mica schists, given their widespread distribution. Boninite is a kind of komatiite with a MgO content of about 10. The texture of both komatiite and komatiite basalt is similar to that of Spinifex. In contrast to the usual olivine found in komatiite and komatiite basalt, boninite contains 16–32% diopside and the same percentage of hypersthene. Only 4% of boninite is indeed quartz. Olivine may be encased in plagioclase grains to provide a Poikilitic texture in thin sections of boninite. Typical carbonatite vein widths are a few centimetres to a metre. Carbonatite veins and veinlets are often discovered near komatiite and komatiite basalt. Well crystalline calcite crystals exhibit an interconnecting structure in both hand specimens and thin slices studied with a petrological microscope. The dark brown carbonate matrix is rife with corroded pyroxene micro phenocrysts, in contrast to the more rare phlogopite, scapolite hornblende, and perthite (of orthoclase and plagioclase).

2. As part of the Delhi super group, the Sandra formations include the predominant phyllite litho unit. Phyllite is a medium-grained, aphanitic rock. Over time, the schist of The Rock transforms into slate. Naturally occurring phyllite occurs in the natural at lower elevations, often in places that have been severely eroded by several low-order drainages. Komatiite, Komatiite Basalt, and Boninite may all be found in dykes and dykelets, with the thickness ranging from ten to thirty centimetres. These protrusions may be found almost everywhere between Chitar and Sendra, and they follow the schistosity of the host phyllite and mica schists. Boninite is a kind of komatiite that contains around 10 percent magnesium oxide (MgO). Komatiite and komatiite basalt also exhibit Spinifex texture. By contrast, boninite has only around 4% quartz and 16-32% diopside but no olivine at all, whereas both komatiite and komatiite basalt have typical quantities of olivine. Olivine is enclosed in plagioclase grains in the poikilitic structure seen in certain thin sections of boninite. Carbonatite veins may be as thin as a few centimetres or as thick as almost half a metre. A common feature of komatiite and komatiite basalt is the presence of carbonatite veinlets and veins. Both the hand specimen and the thin slice under the petrological microscope reveal an interlocking structure in the well crystalline calcite crystals. Dark brown carbonate host micro phenocrysts of corroded pyroxene; phlogopite, scapolite hornblende, and perthite are also present (of orthoclase and plagioclase).

3. Andesite with a maenocratic appearance has been found in both field and laboratory settings. It has been shown that the average percentage of quartz is less than ten, that of plagioclase is between twenty-five and sixty, and that of orthoclase is between one and thirty. The new host still contains remnant cores of hornblende pyroxenes. The typical concentrations of diopside and hypersthene are, respectively, 12 and 32 percent. The highest points of the landscape have been capped by massive diorite formations. Diorite, it turns out, is mainly plagioclase feldspar and looks grey in the field. Diorite, a kind of holocrystalline rock, with grains that are about in between those of granite and quartz. In comparison, plagioclase feldspar contains just 15% hypersthene and 30% quartz. The diorite seems to be the culmination of igneous activity during the formation of ophiolite components, with quartz veins of this component following soon after.

Petrogenesis Model of Evolution

Neither Y nor Cr is affected by the processes that generate heterogeneities in the convecting upper mantle. A primary magma composition model and projection may be made in the form of a partial melting trend annotated by melting degree (as expected from meteorite compositions, mantle xenoliths, and estimations Cr and Y, respectively). Crawford et al. (1981) proposed a petrogenetic pathway as an explanation for the formation of SSZ ophiolite, and this was subsequently cited by Pearce et al (2016). Through the use of data from the Chitar-Sendra ophiolite, we were able to put the theories stated in Figure-3 to the test and show how the differences in Y and Cr between MORB, IAT, and boninite may be explained. The Phulad ophiolite, and more specifically the Chitar-Sendra section, is typical of ophiolites that form in the suprasubduction zone (SSZ), and its formation and evolution follow a well-established pattern. This distribution illustrates the universal methods through which SSZ ophiolites form. Figure 4 depicts a sequence of occurrences that includes the following: The fifth stage, often dubbed the "resurrection stage," is when most SSZ ophiolites are obducted onto a passive edge. This process, however, seems to have been skipped through in the instance of the Phulad ophiolite's Chitar- Sendra portion. In an SSZ, extensional tectonics and rifting are required for the development of depleted geochemical basaltic magma (Murton, 1989). Geological evidence indicates that subduction happened in the area before to the emergence of extensional tectonics (Lipman, 1980; Wilson, 1989). As with other rift-related basalts, the Chitar-Sendra basalt has clear subduction-related characteristics (Wilson, 1989). In certain geological rifts, carbonatite magmatism coexists with basaltic magmatism, displaying a change from subalkaline to alkali basalts. Rift zones have been proven to include records of basalts with widely varied chemical compositions in close spatial and temporal relation (Wilson, 1989), with the sides of rifts often being more alkaline, as seen in Chitar-Sendraophiolite owing to the presence of Carbonatite.

Discussion and result

Our present understanding of tectonic processes allows for the possible emergence and development of ophiolites of the SSZ type; these ophiolites often occur in the early phases of oceanic lithosphere subduction (Stern and Bloomer, 1992; Shervais, 2001; Wakabayashi et al, 2010; etc). Crust thickens from the east to the west because to subduction in the west, as well as the mafic and ultramafic rocks of the Chitar-Sendra Ophiolite complex, and the shallow water deposits in the west. During the creation of the Chitar-Sendra Ophiolite, it is hypothesised that fluids migrated from the subducting slab into the mantle, which might account for the presence of LILE-enrich melting in the rocks of this ophiolite. Both high LREE fractionation and low melt may be inferred from LREE abundances. The presence of E-MORB in the mafic and ultramafic rocks of the Chitar-Sendra massif is not unexpected given that enrichment may be linked to fluid addition. Furthermore, the LILE (K, Rb, Cs, Ba) and the LREE are enriched in supra subduction zone ophiolite by the aqueous fluid evacuated during subduction, whereas the HFSE is depleted (Ti, Nb, Ta, Hf). If the rate of partial melting rises, the supply of HFSE might be at jeopardy. Increased inflow of asthenosphere from MORBs melts the'refractory' asthenosphere under the growing lithosphere in a wedge formed by the two. This explains why melts lack the HREE and HFSE seen in abundance in oceanic basalt. Increased circulation of slab-derived melts may reduce the solidus in the reflect in LILE-enriched and HFSE-depleted patterns. An increase in melting of the refractory asthenosphere mantle may account for the flat and homogenous REE pattern. Wakabayashi et al. (2009), Shervais (2001), and Stern and Bloomer (1992) all agree that the proposed model of the Chitar-Sendra Ophiolite is in line with the Supra Subduction paradigm (2001). (2010). However, boninite magma activity has been contained in the upper crust, above the subduction zone (Taylor et al., 1994). Since the Boninite magma is the source of pyroxenite and other mantle series relic rocks, it is probable that the ophiolitic complex created the supra-subduction zone environment (e.g. Edwards, 1995; Varfalvy et al., 1996; Suhr and Edwards, 2000). However, we have identified locally in the Oman ophiolite's mantle severely depleted rocks and refractory pyroxenite that provide evidence of arc magmatism. Despite the presence of harzburgite, a mineral with a composition very close to that of the deep mantle, this is still the case (e.g., Boudier and Coleman, 1981; Kelemen et al., 1995; Kadoshima, 2002; Taka- zawa et al., 2003). The Chitar-Sendra ophiolite suite is a possible subsurface equivalent of arc-like volcanic rocks like Boninite. Igneous rocks with an arc character were transported into the oceanic lithosphere by oduction, which occurred at the same time as subduction (Arai, 1995; Arai et al., 2004). This level of precision is essential for the effective operation of ophiolite, a kind of beached ocean bottom. Based on what we know so far, the transition from subalkaline to alkaline basalts may have taken place in certain geological rifts where carbonatite and basaltic magmatism occurred at the same time (Wilson, 1989). Carbonatite, boninite, and komattite Basalts, each with their own unique chemical compositions, are found in the Chitar-Sendra ophiolite, which serves as an outstanding example of this phenomenon inside rift zones (Wilson, 1989). More alkaline conditions may be found at rift zones' peripheries than in their cores. The Chitar-Sendra portion of the Phulad ophiolite, for instance, shows that it forms using the same methods as other ophiolites. This is also true of other ophiolites that form in the SSZ. As can be seen here, there are three possible time periods during which ophiolites developed. In the first stage, dubbed "birth," arc tholeiite lavas erupt and a sheeted dike complex forms over a newly created or reorganised subduction zone. The second stage, dubbed "youth," involves extensional deformation of the plume as a result of the ongoing melting of'refractory' asthenosphere (depleted during birth) in response to fluid flow from the subducting slab. The first and third stages of the development of the Chitar-Sendra ophiolite have been assigned a wide range of times. The resurrection stage of the Phulad ophiolite, in which the ophiolite is inserted by obduction onto a passive edge or, alternatively, by accretionary uplift with continuous subduction, has not been observed along the Chitar-Sendra segment. This research suggests that refractory rocks including boninite, komatiite basalt, and komatiite itself are present in the Chitar-Sendra ophiolite. Refractory mineral chemistry and lithology identify Boninite/Komatiite Basalt/Komatiite as the byproduct of high-degree partial melting facilitated by H_2O-rich influx. Trace elements similar to those in boninite were discovered in a melt that was in equilibrium with pyroxenites and clinopyroxenes. Magmatism at higher tectonic depths may have resulted in the formation of the refractory Boninite/Komatiite/Basalt/Komatiite suite. Finally, in the mantle section of the ophiolite, rocks like the Boninite/Komatiite Basalt/Komatiite suite, which are characteristic of a supra-subduction zone environment, may be present. An ophiolite is a mass of igneous rocks with a "arc signature" formed when oceanic lithosphere is obducted. In rocks older than the tertiary, Ophiolites with mineralization are very rare.

Conclusion

The Chitar-Sendra Superstition Zone may have been the place where ophiolites first formed during the Mesoproterozoic epoch of the Earth's history. Ophiolites may be found within the Phuld Ophiolite Suite; nevertheless, real oceanic ophiolites are very rare (POS). These ophiolites evolved as a consequence of the opening of the Aravalli oceanic basin during the Paleoproterozoic. This event contributed to separate the eastern Bundelkhand craton from the western Marwar craton. The Phulad Ophiolite Suite (POS) ophiolites are essential markers for understanding the tectonic setting of the closure of the oldest ocean basin portion of the Pan-African and Brasiliano Ophiolite, as well as the activities that preceded the collision of the eastern Bundelkhand craton and the western Marwar craton. These ophiolites were formed when the oldest ocean basin portion of the Pan-African and Brasiliano Ophio

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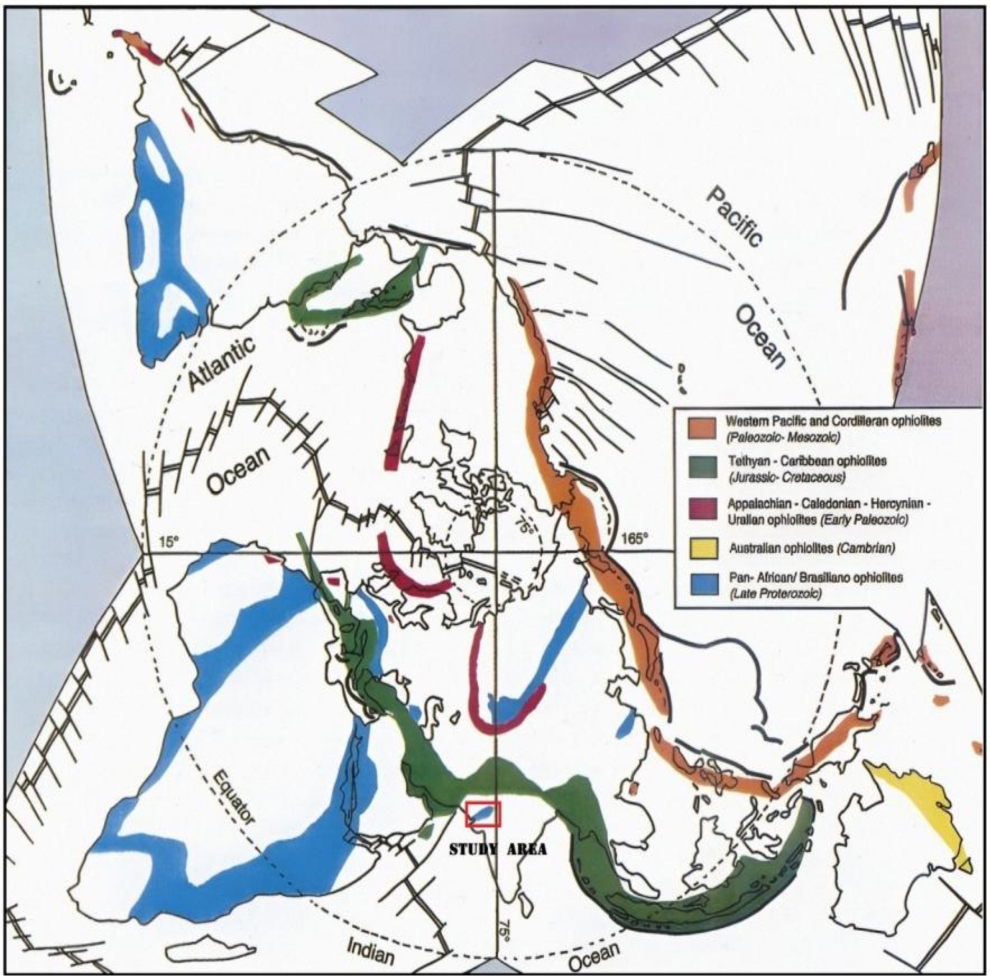

Figure 1- Global distribution of Proterozoic and Phanerozoic ophiolite belts and modem mid-ocean ridge systems (fine double lines) on a North polar projection map (base map from Coleman 1977). Bold black lines represent trenches of modem subduction zones. (Modified after Yildirim Dilek (2003)

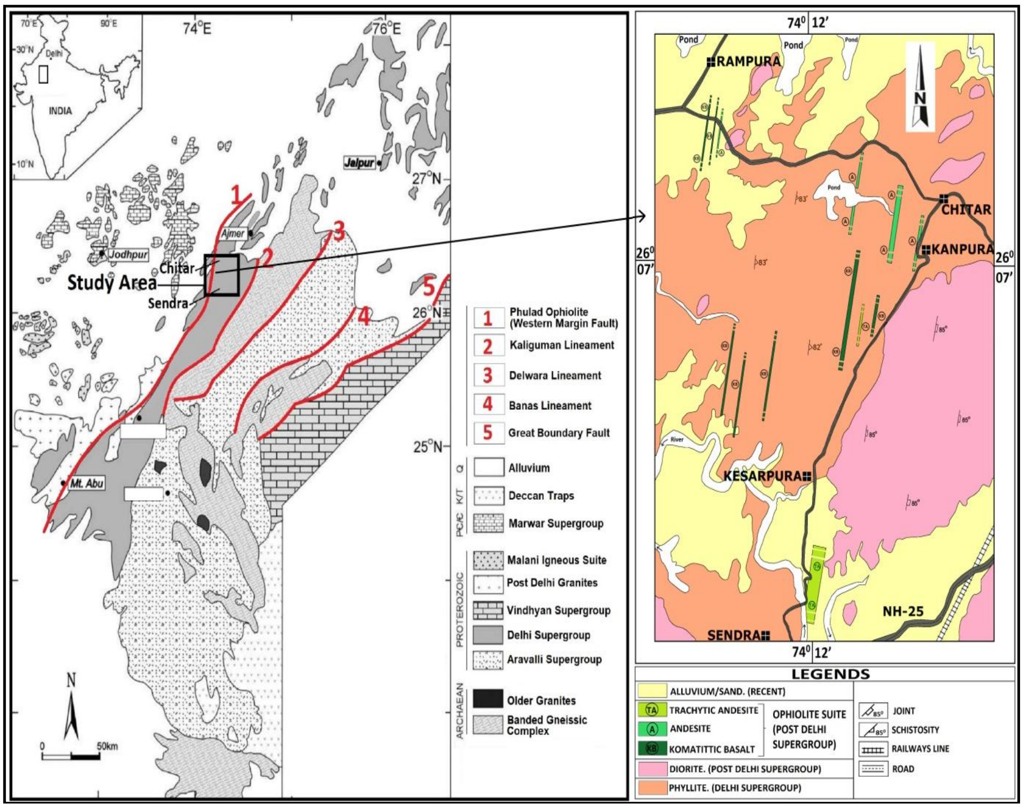

Figure 2-Geological map of Chitar Area, Phulad Ophiolite Suite, Pali District, Rajasthan.

Table 1: Stratigraphic Succession at Chitar- Sendra Area.

Recent	**River Alluvium, Blown Sand and Soil.**	
Supergroups	**Ophiolites units (Post-Delhi)**	**Diorite (1020 Ma) Andesite Carbonatite Pyroxenite Boninite Komatiite Basalt Komatiite**
Delhi supergroup (Meso-Proterozoic)	**Sendra formation**	**Phyllite and Schist Bar Conglomerate**
Basement not exposed		

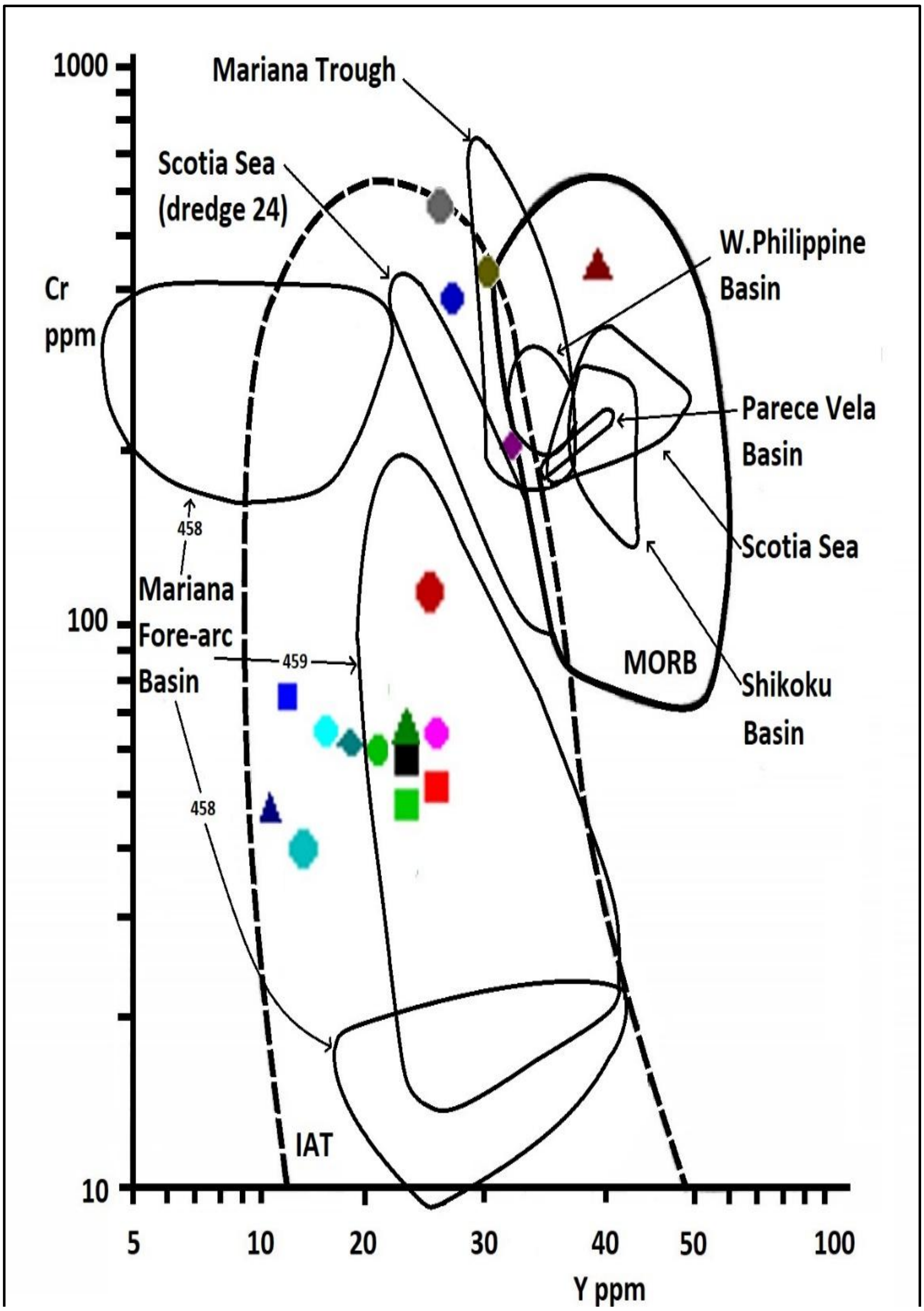

Figure 3 - Ophiolite Components (Boninite/ Komatiite/ Komatiite Basalt/ Pyroxenite/ Carbonatite/ Andesite) of Chitar-Sendra area showing island-arc tholeiites. Affinities, when plot in original Cr-Y dicrematory diagram by Crawford et al. (1981), who utilized data from various workers

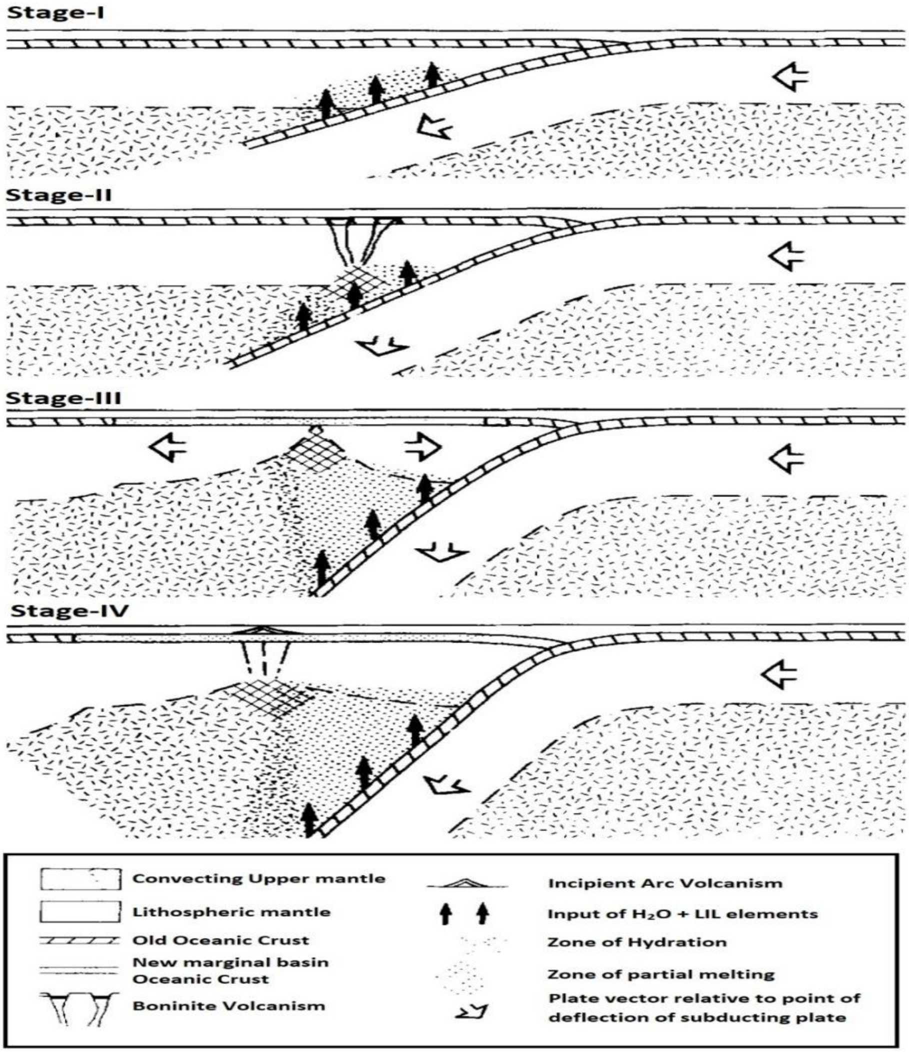

Figure-4 Proposed schematic model for the initial stage of evolution of ensimatic marginal basin at Chitar-Sendra south Delhi Fold based on work of Pearce, et al (2016). Hydration of Sub- Oceanic lithosphere immediately follows Subduction (Stage-I). Melting of this mantle source generates initial Boninitic magmatism (Stage-II) which mark start of Pre-arc spreading event that forms Ophiolites (Stage-III). This is follows by sub-marine arc volcanism (Stage-IV).