inanimate elements are fairly clear; yet reproducing these routes in the laboratory is a task faced with numerous problems. However, there is no doubt that life appeared as the outcome of protracted chemical evolution that obviates the need for any divine intervention. The emerging technology of gene sequencing is opening new windows into life's ancestry and might one day also answer the question of how life appeared on our planet

GEOLOGY AND GEOCHEMISTRY OF ARCHAEAN GHATTIHOSAHALLI MAFIC-ULTRAMAFIC COMPLEX, CHITRADURGA, KARNATAKA

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EXTENDED ABSTRACT

Introduction

The Ghattihosahalli belt is one of the best-preserved supracrustal belts of Karnataka, which occurs close to the western margin of the main Chitradurga schist belt. The 0.5 to 1.5 km wide belt extends for over 25 km from west of Mayakonda in the north to east of Talya in the south. The study area constitutes a small block in the southern part of the belt occupying the area between east of Janakal and south of Talya, wherein the belt occurs as a continuous curvilinear mega-enclave with ESE to SE trend, which epitomises the whole of Ghattihosahalli belt.

Geology

The belt comprises two major geological components (Plate 1). The older component occurs mainly in the western part of the area and belongs to the Sargur Group. The younger component, which occurs, in the eastern side of the belt constitutes the lower part of Bababudan Group of the Dharwar Supergroup. The Ghattihosahalli belt is surrounded by the peninsular gneissic complex in the eastern and northern peripheries.

Sargur Complex: The supracrustal rocks underlying the basal unconformity and invaded by the PGC belong to Sargur group. As the major event is dated around 3000 Ma, the Sargur rocks could be of early to middle Archaean, >3000 Ma age (Swami Nath and Ramakrishnan, 1981). The Sargur supracrustals in Ghattihosahalli belt are predominantly meta-ultramafics, mafics and associated subordinate metasediments, disposed without any apparent stratigraphic order.

Ultramafics: The ultramafics are represented by the serpentinites (peridotitic komatiites) and other variants exhibiting undoubted spinifex texture (Viswanatha et al. 1977 and Nayarana and Naqvi, 1980) and locally deformed nodular structures recorded at places in the belt. The occurrences of these structures are the most significant features confirming the extrusive origin (komatiites) as described by several workers (Viljoen and Viljoen, 1969a, b, 1982; Nesbitt and Sun, 1976; Arndt et al. 1977; Nisbet et al. 1977; Brooks and Hart, 1974; Arndt and Brooks, 1980).

Serpentinite is feebly schistose and essentially made up of antigorite and fibrous chrysotile, with minor amounts of carbonate, chlorite, tremolite and talc. A thin section of the spinifex textured portion exhibits of relict olivine grains largely altered to serpentine. A couple of sections locally show poorly preserved micro-spinifex texture, which favours the komatiitic origin of these rocks. Schistose ultramafic rocks are dominantly made up of actinolite with minor amounts of chlorite and talc.

Amphibolites: The ultramafic flows occur in close association with basaltic komatiites and tholeiitic rocks and are now represented by deep green streaky/shiny amphibolite (meta-pyroxenite) and finely foliated amphibolite respectively. The streaky/fibrous amphibolite (basaltic komatiites) essentially consists of prismatic hornblende with acicular needles of green actinolite with considerable amount of plagioclase, a few relict clino and orthopyroxenes, chlorite, epidote, minor quartz and carbonates withaccessory sphene. This rock is generally massive, compact and poorly foliated at places and exhibits sub-hypidiomorphic

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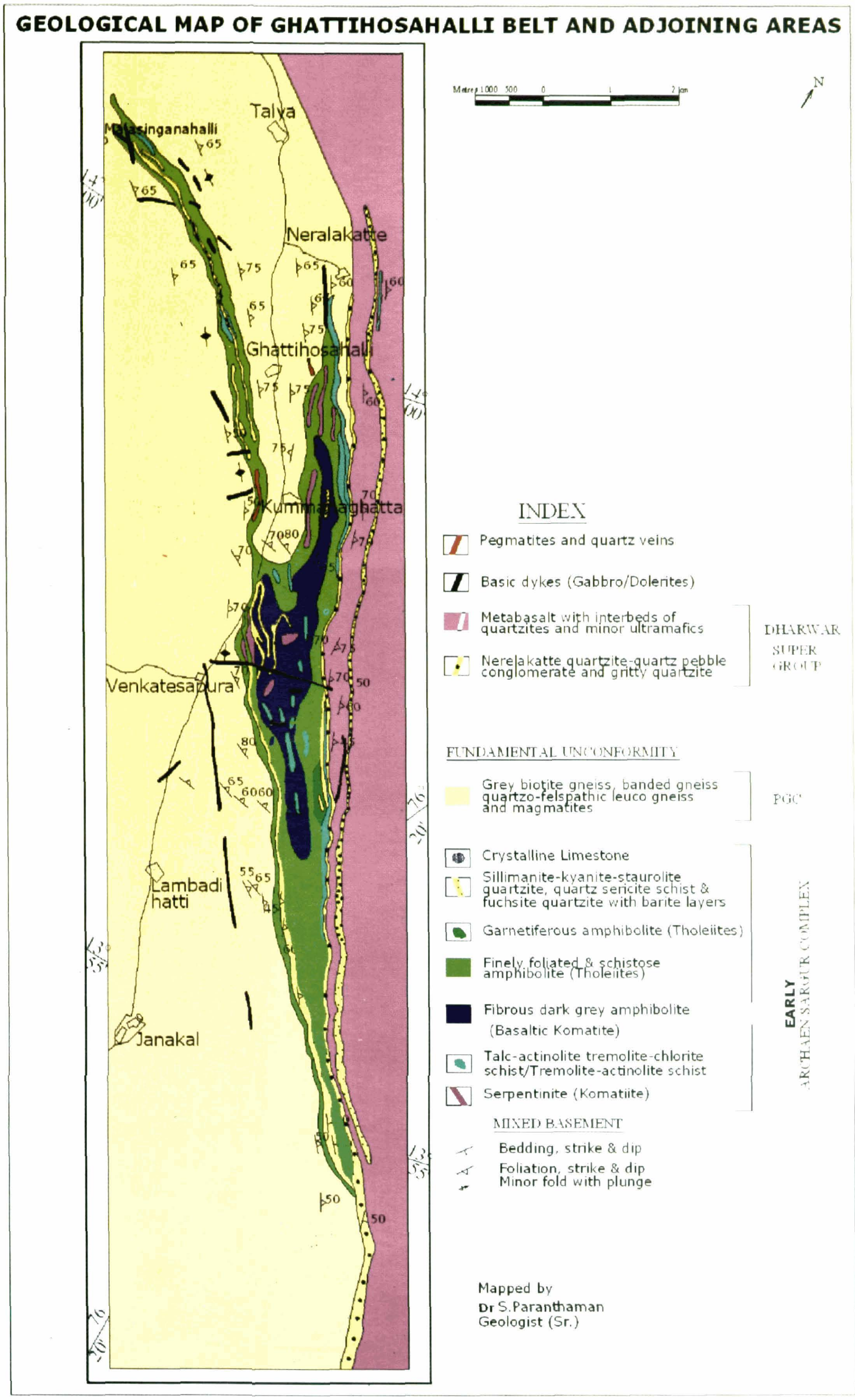

Plate 1. Geological map of Ghattihosahalli belt and adjoining areas.

texture The finely foliated amphibolite (tholeiite) is often banded and characterized by the parallel alignment of prismatic dark green hornblende and tabular plagioclase crystals Magnetite and sphene are the accessory minerals Finely foliated amphibolite locally shows evidence of granitisation along the contact with the PGC

Ultramafic rocks, streaky amphibolites and foliated amphibolites though occur together, do not show any gradational contact However, these rocks are found deformed with the other associated lithounits The ultramafics and streaky amphibolites notably show a progressive change in their composition from ultramafic to mafics indicating their genetic link The high Mg basalts (streaky amphibolite) might have evolved from a high silica and low magnesian magma source controlled dominantly by the fractional crystallization of pyroxene and plagioclase with little olivine and opaques These are emplaced sequentially as komatiitic basalt and by progressive crystallization of residual melts left after the removal of olivine controlled komatiite lavas The tholeiitic (finely foliated) amphibolite is evolved mainly from the plagioclase and pyroxene fractionated and Mg-depleted upper mantle source by the partial melting at shallow depth

Metasediments: The occurrence of a variety of metasediments associated with the mafic-ultramafic rocks constitutes a characteristic feature of the Sargur complex in Ghattihosahalli belt Though the belt consists of 10-15% metasedimentary rocks, its association with sub-aqueous volcanics is very significant in order to understand the Archaean sedimentation and volcanism

Petrographically, the quartzites (cherts) are made up of quartz ± kyanite ± staurolite ± sericite ± fuchsite ± sillimanite ± accessories (rutile and apatite) Baryte occurs as conformable but discontinuous thin bands and lenses in a narrow zone within the quartzite close to the underlying metabasics and meta-ultramafic units Baryte bands are largely confined to the chromiferous quartzite horizon In thin section, the barite displays granoblastic texture comprising interlocking to polygonal grain boundaries Crystalline carbonates occur as lenticular bands and are seen closely associated with streaky amphibolite (basaltic komatiites) The field associations of metasediments close to the underlying mafic-ultramafic flows and their petrographic characters clearly indicate that they are volcanic-exhalates

Peninsular Gneissic Complex: The Peninsular Gneisses occur extensively all along the western and northern parts of the Ghattihosahalli belt They exhibit varying physical and mineralogical characteristics and on this basis, they can be distinguished into grey biotite gneiss, quartzo-feldspathic gneiss and migmatites The PGC exhibit complex relationship with older and younger supracrustals Sargur supracrustal rocks generally occur as enclaves and xenoliths within the PGC indicating intrusive nature of the latter and quartzo-feldspathic veins resulting in local migmatisation often traverse the supracrustal rocks

Bababudan Group (Lower Dharwars): The lower part of the Dharwar belt is well exposed to the east of Ghattihosahalli and represented by Bababudan group It is marked by a typical oligomict conglomerate overlain by a rhythmic sequence of amygdular metabasalt and cross-bedded quartzites The nature of contact between Bababudan rocks and the Sargur-PGC is generally sharp and at placed show tectonic intermixing especially with ultramafic rocks These rocks have distinct pattern, orderly development with a definite sequence in contrast with the Sargur complex in GHB The massive metabasalt indicate high degree of deformation and related schistosity development under green schist facies metamorphism The presence of vesicles and amygdules in metabasalt and sedimentary structures within the interbedded quartzite indiate sub-areal to shallow, possibly platformal conditions with mafic volcanism

Basic Dykes : Numerous basic intrusives (representing dolerite and gabbro) are seen intruded into all the three principal geological units Generally they are emplaced parallel to the trend of the enclosing rock formation and possibly represent weak planes paralleling the regional grain They are fresh and bouldery in nature and are characterized by spheroidal weathering They perhaps represent final phase of intrusive activity in the Dharwar Craton Petrographically, the rock shows ophitic and sub-ophitic texture, wherein the short stumpy prisms of augite are seen to have partially intergrown laths of plagioclase, which locally show feeble zoning Minor amounts of hypersthene and Ti- rich biotite, besides skeletal magnetite constitutes the rock

Structure

Ghattihosahalli belt consists of three tectonic components, each having a structural history of its own These tectonic components are the Sargurs, the PGC, which encloses Sargurs and the volcano-sedimentary association of Bababudans, which forms the youngest unit overlying Sargurs and the PGC The Sargur tectonic unit, though oldest of all is occupying a position of synformal keel within the PGC and the whole structural unit is folded into northerly plunging antiform with the Kummanaghatta component of the PGC in the core. The Bababudan rocks lying eastward are mainly in the structural depression representing the relict of the original Dharwar basin.

Mapping has also brought out the impersistent and cofolded nature of Sargur lithounits such as fuchsite quartzite, quartzites, barites, etc. The PGC has more or less conformable planar structure and appears to be largely cofolded with the Sargur lithologies. In contrast to this, Dharwar rocks display an orderly sequence of development.

The detailed mapping of GHB confirmed the presence of a significant structural discordance in the form of angular unconformity between PGC-Sargur and the Dharwar cover rocks (Plate 1). This is evident by the contrasting structural trends of these schist belts. The PGC-Sargur rocks have NW-SE trend, whereas the Dharwar cover rocks have N-S to NNW-SSE trends. The Sargur complex of GHB enclosed within the PGC is overlapping along its southern extension by the Bababudan rocks of Dharwar Supergroup. This clearly proves that Sargur–PGC probably suffered an earlier deformation prior to the commencement of Dharwar sedimentation. Though the earlier trends have been largely modified by the subsequent Dharwar orogeny, it is substantially preserved along the western margin of the supracrustal belt.

The angular relation has a time connotation between the events of evolution of Dharwar basin and the development of PGC, with its Sargur mega enclave. This aspect is particularly important because some workers held the view, that there is a structural unity among Sargurs, PGC and Dharwars and therefore, there was no break in the events.

The Sargur complex of GHB, with its heterogenous rock types represent the earliest events of sedimentation intermingled with magmatic activity in an oceanic environment, followed by the evolution of tonalite-trondhjemite dominated PGC enclosing the Sargur rocks. There was a period of deformation before the initiation of the Dharwar basin and this was followed by a new cycle of sedimentation of magmatic activity. Thus, the angular unconformity at the base of the Dharwars is of considerable stratigraphic and geodynamic importance in separating the event history of Sargurs and Dharwars. The presence of angular unconformity further proves that the Sargurs of GHB are not related to Dharwars, but they are much older.

Metamorphism

It is observed that the late Archaean Babadudan Group of rocks have metamorphosed under low-grade greenschist facies conditions. The early Archaean Sargur rocks are the products of the synkinematic metamorphism and migmatisation under upper amphibolite facies conditions in GHB. Contrasting grade of metamorphism across an angular unconformity marks an important criteria and strong evidence to prove that these two supracrustal rocks have their own identity and represent two separate metamorphic domains.

Geochemistry

Major, minor and trace elements plots on various discriminant ternary and binary diagrams of mafic-ultramafic rocks of Sargur complex in GHB, clearly illustrate a progressive chemical variation from ultrabasic to basic compositions and the associated sediments show volcanogenic character. The field associations together with the geochemical character suggests that, the mafic-ultramafic rocks formed by two discrete volcanic suites [Komatiite and tholeiitic series] and are evolved from the mild LREE enriched and flat unfractionated HREE mantle sources at varying P-T conditions.

Komatiites form by partial melting of magnesium enriched deep mantle at high termperature in excess of 1600°C from the sources that ascend from still greater depths from mantle plumes, that probably followed an adiabatic path to the surface (Arndt, 1994). The associated komatiitic basalt is evolved by the progressive fractional crystallization of residual melts left after the removal of olivine controlled komatiitic lava. The tholeiite is evolved from the magnesium depleted source controlled mainly by the plagioclase and pyroxene fractionated mantle source derived by the partial melting at shallow depth at a temperature below 1250° C (Arndt, 1994). The Ti-Z and Ti-Y chondritic ratios, negative correlation of vanadium against MgO and variation in REE abundances in mafic-ultramafic rocks clearly demonstrate the existence of two volcanic sources in Sargurs.

In contrast to Sargur mafic-ultramafic rocks the meta-lavas of Bababudan Group are essentially tholeiites and their geochemical character show more evolved nature, when compared to the primitive unfractionated komatiite and tholeiitic lava series of Sargur Complex in Ghattihosahalli.

The GHB mafic dykes are much-evolved tholeiites showing higher Mg and Fe contents. The dyke samples show low potassic tholeiite and transitional oceanic-tholeiitic characters. As the geological setting clearly indicates their continental emplacement, the apparent oceanic nature may be explained by magma generation in a thin crust under rift like environment. These dykes appear to be mineralogically and compositionally similar to the early Proterozoic dolerite dykes which intrude many other Archaean terrains apparently during final craton stabilization (Weaver, 1990)

Conclusions

The lithological association, diagnostic structures and textures substantiated by the detailed petrography and geochemistry indicate that the Sargur supracrustal rocks in Ghattihosahalli belt (GHB) were evolved largely in an oceanic environment during early Archaean times in the Dharwar Craton

The ultramafic (komatiitic) volcanism has taken place initially with the deposition of volcanic exhalative sediments such as cherty quartzites and associated barite seams, soon after their formation Simultaneously the liberation of carbon dioxide during volcanic eruption caused intensive carbonation of the ultramafic lavas, which has resulted in the precipitation of exhalative carbonates at a few places The associated lavas of basaltic komatiites were evolved by differentiation from the komatiitic lavas subsequently the tholeiitic rocks evolved from a different volcanic source

The superimposition of later tectonic events, medium to high grade metamorphism, migmatisation and syn-tectonic invasion of tonalite-trondhjemite-granodiorite (TTG), has resulted in the disposition of already deformed Sargur rocks in GHB as synformal keels and the whole structural unit is folded into northerly plunging antiform roughly in a N-S direction This has also caused the total disruption of Sargur mega-structures and sequences now occurring as tectonically interleaved patches

The Bababudan rocks in GHB represent a new cycle of sedimentation and magmatic activity These rocks were deposited over the already deformed and eroded surfaces of the PGC enclosing Sargur Supracrustal rocks They occur in a normal position trending NNE-SSW, in contrast to that of Sargur and PGC, which have a broad NW-SE trend The entire belt of Sargur rocks disappears beneath the Bababudan unit of the GHB to an angular unconformity This angular relationship between Dharwar basin and the development of PGC with Sargur enclave indicate the existence of an ancient volcanic cycle of Sargur complex and a late Archaean-Proterozoic Dharwar cycle in the Ghattihosahalli belt

Subsequent to the evolution of Bababudan basin, an episode of intense tectonism in the Craton resulted in tectonic slicing up of some ultramafic rocks from beneath, which are now occurring as narrow linear bodies within the above mafic platform The mafic dykes, which intrude the GHB, are Proterozoic dolerite dykes and represent the end phase of basic magmatism apparently related to the stabilization of the craton

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