Archaean greenstone belts of the eastern Baltic and the southern Indian shields — a comparative study

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A comparative study of the Archaean greenstone belts of the same time span (3.3 Ga to 2.5 Ga) in the Dharwar craton of southern India and the eastern Baltic shield of Karelia, USSR, shows some significant differences in their evolutionary trend. Whereas detrital sedimentary rocks occur throughout the stratigraphic succession in the southern Indian shield, they are restricted to the upper part of the sequence in the eastern Baltic shield. Chemogenic sediments (banded iron- and manganese-formations and carbonate rocks), dominant constituents in the Dharwar belts are poorly developed in the Baltic shield. Stromatolites are absent in the Baltic greenstone belts, but occur in profusion in the Dharwar belts. Bimodal/polymodal volcanic assemblages, together with immature sediments in the Baltic shield, point to an island arc setting, whereas association of both mature and immature sediments with bimodal volcanics in the Dharwar belts favours a back-arc environment.

POST-accretionary early history of the earth is preserved in the Archaean (> 2500 m.y.) geological record. Greenstone–granite and gneiss–granulite provinces constitute the Archaean terranes. Study of these rock formations tells us about the nature and evolution of the early crust hydrosphere, atmosphere and biosphere. The tectonic environment in which the Archaean greenstone belts developed and the trend of evolution they followed constitute some of the major aspects of study of the earth's history during the Archaean.

Greenstone belts evolved throughout the Archaean and Proterozoic times[1]. The Archaean belts have been classified into early (> 3300 m.y.), middle (3300 m.y. to 2900 m.y.) and late (2900 m.y. to 2500 m.y.) greenstone belts[2]. Each of these classes is characterized by distinctive tectonic, environmental, volcanic, sedimentational and biological signatures, implying a secular change in characters. However, as recent studies emphasize, greenstone belts evolved contemporaneously could be characterized by widely different evolutionary trends, depending on the sedimentary-tectonic environment in which they developed. The Archaean greenstone belts and the gneiss–granulite belts of the eastern Baltic shield in Russia and the Dharwar craton in southern India which evolved during the same time (3100 m.y. to 2600 m.y. ago) provide an opportunity for understanding this aspect.

Greenstone belts of the eastern Baltic shield

The oldest rocks in the eastern Baltic shield and in the Dharwar craton are > 3.1 to 3.2-Ga-old gneisses acting as a basement or a nucleus on which or bordering which the greenstone belts developed[3–8]. In the Karelian province of the Baltic shield, successively younger greenstone belts (Figure 1) developed from east to west between 3.1 and 2.6 Ga (refs. 5,9). Bimodal mafic-felsic as well as polymodal calc-alkaline volcanic associations are equally well developed in the Baltic shield greenstone belts[10]. Peridotitic and basaltic komatiites frequently occur in the lower part of the volcanosedimentary sequence. In some belts (Hautavaara, Oster, Parandovo) the lower part of the section is represented by andesite and dacite lavas and tuffs. Sedimentary rocks are subordinate, chiefly represented by immature polymictic conglomerates and graywackes. Banded iron formations are restricted to the

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Figure 1. Geological map of the Archaean terranes of Karelia and Kola peninsula of the eastern Baltic shield, Russia.
A, Saamian basement complex; B, Lopian greenstone belts; C, Belomorian mobile belt; D, other Proterozoic rocks; E, platform cover. 1, Hautavaara; 2, Koikari; 3, Palaja Lamba; 4, Oster; 5, Parandovo; 6, Kamennoozerskaya; 7, Kostamooksha; 8, Jalonvaara; 9, Kuhmo–Suomussalmi; 10, Hizovaara; 11, Polmos–Poros; 12, Kaskamskaya; 13, Allarechenskaya; 14, Priimandrovskaya; 15, Zaimandrovskaya (Olenegorskaya); 16, Terskaya.

Kostamooksha belt in western Karelia and Olenegorskaya region in the Kola peninsula. Carbonate rocks at the top of the sequence are practically of negligible thickness. The entire supracrustal assemblage designated as Lopian accumulated in a relatively mobile environment. The Lopian assemblages are metamorphosed under greenschist to lower amphibolite facies. In the northern part of Karelia in the Belomorian belt occurs a suite of high-grade metamorphosed volcanic and sedimentary rocks associated with ortho- and paragneisses referred to as Saamian. The stratigraphic position of the Saamian Group with reference to the Lopian is a subject of debate. One school believes that the Saamian is older than Lopian and considers that the Lopian sequence accumulated on tonalites which were emplaced during Saamian Orogeny dated at 3.1 Ga (refs. 5,10). Another school considers the Saamian to be high-grade metamorphosed Lopian sequence. Lopian–Saamian interrelationship in the northern part of Karelia (Hizovaara area) and in the southern part of the Kola Peninsula (around Kovda) shows that the Lopian mafic dykes, pillow lavas and volcaniclastic rocks grade into migmatitic gneisses and garnetiferous amphibolites (Figure 2), with polymictic conglomerates migmatized at some places (Figure 3). This suggests that the Saamian Group does represent high-grade metamorphic equivalents of Lopian rock formations, proving a transitional relation between the low- and high-grade terranes.

Greenstone belts of the southern Indian shield

Dharwar greenstone belts of southern India (Figure 4), although developed during the same time (3.0 Ga to 2.6 Ga ago)[7], differ from the greenstone belts of the Baltic shield in many respects. They are composed dominantly of bimodal mafic–felsic volcanic assemblage[11]. Komatiites are subordinate and occur at different stratigraphic levels[12–15]. Some of the green-

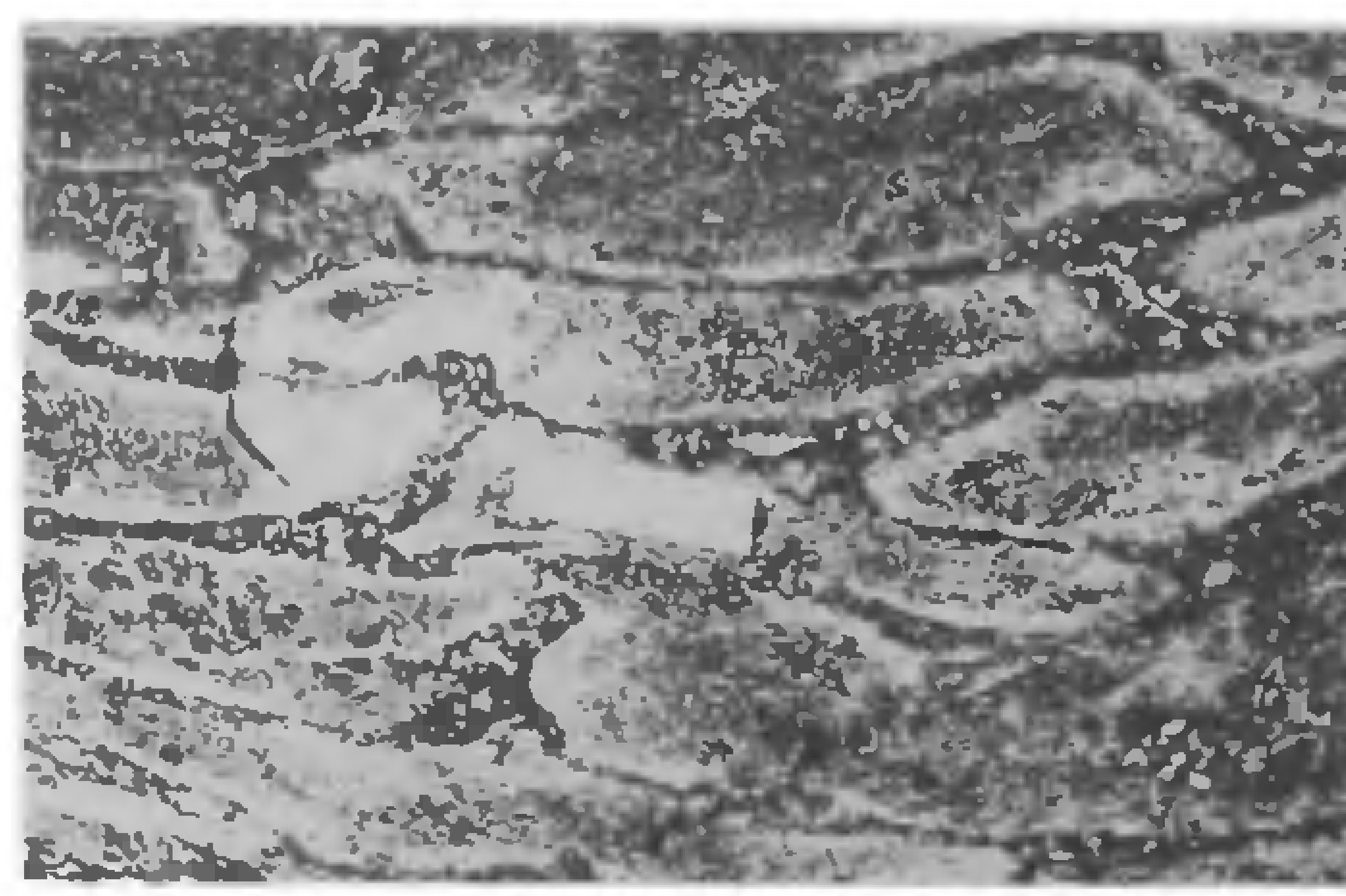

Figure 2. Pillow lava deformed and metamorphosed to garnetiferous amphibolite, Hizovaara.

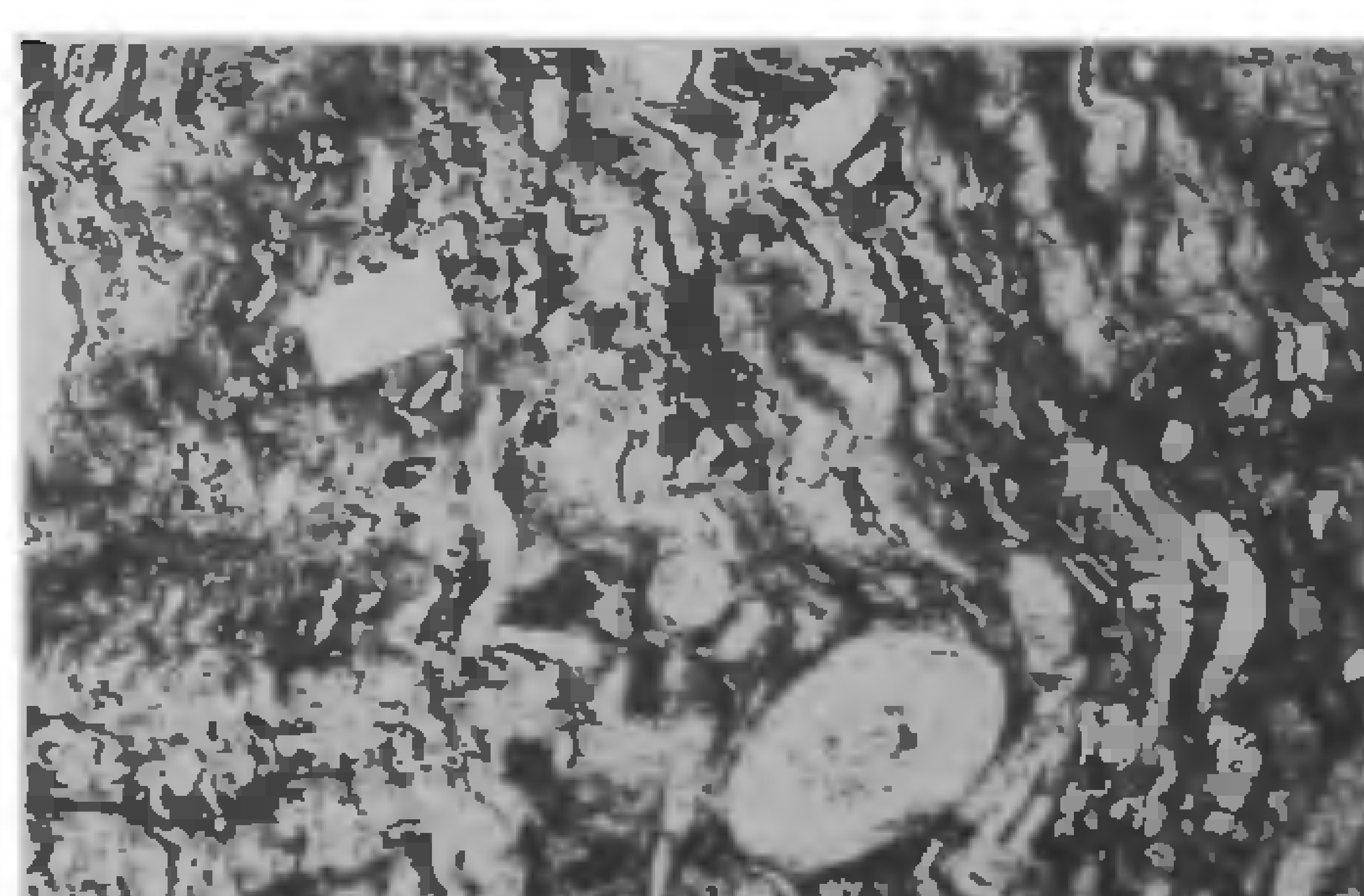

Figure 3. Deformed and migmatized conglomerate, Tolstik Point, Belomorian belt.

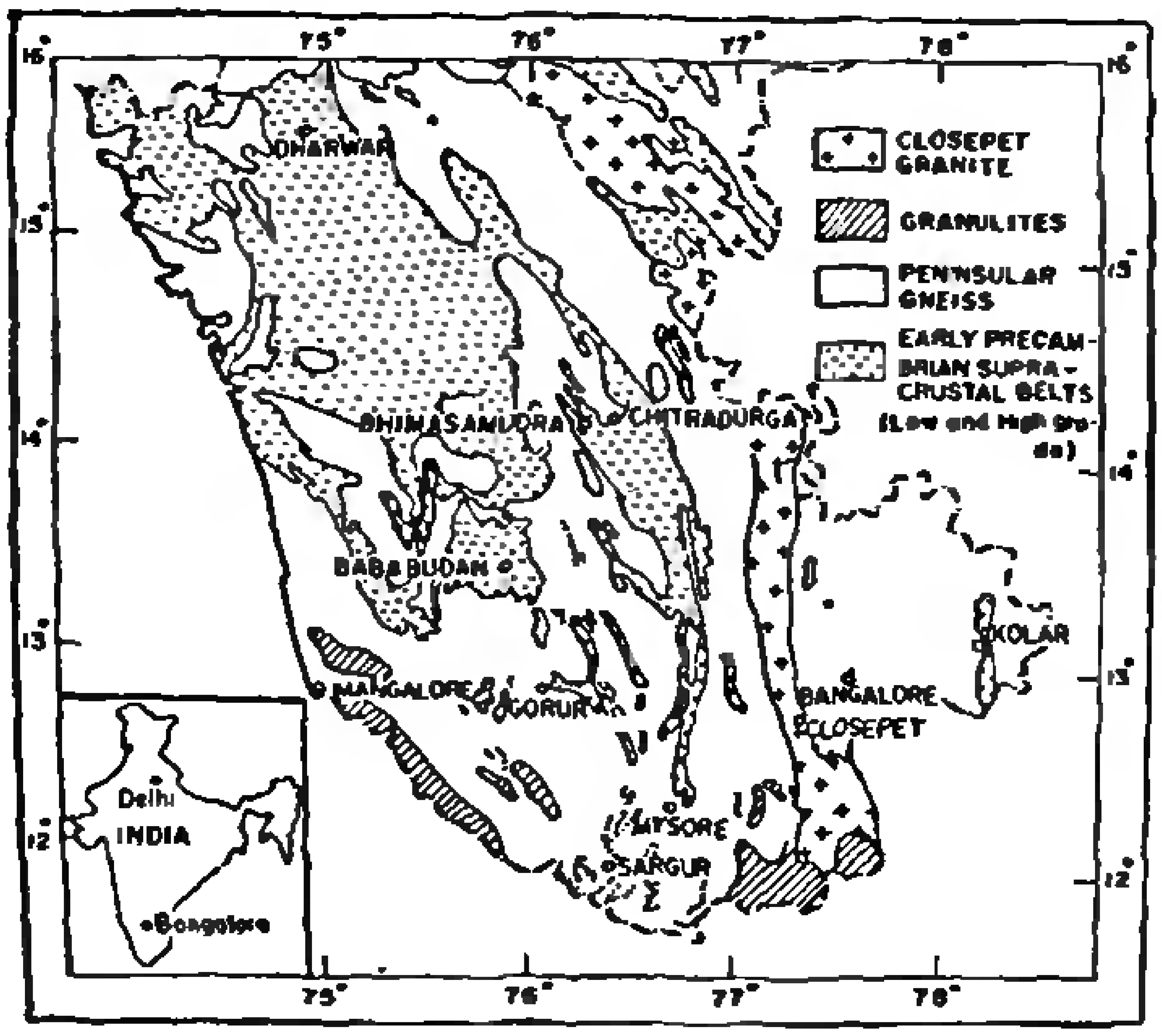

Figure 4. Geological map of the Dharwar craton, southern India.

stone belts are dominantly composed of intrusive-layered ultramafic–mafic complexes whereas sedimentary rocks are more abundant in some other belts. Platformal and shelf zone sediments comprising uraniferous quartz pebble conglomerates, cross-bedded clean quartz arenites (Figure 5), stromatolitic carbonate rocks (Figure 6), extensive banded iron and manganese formations are all well developed in the lower part of the Dharwar sequence[16–19]. These, together with the layered igneous complexes seen in the lower part of the sequence, imply a stable crustal environment for sedimentation, volcanism and intrusive igneous activity[18,19]. The upper part of the Dharwar sequence with a polymictic conglomerate–graywacke–pillow lava association indicates a mobile environment[16,19,20]. Thus the evolution of the basin in which the supracrustal rocks

Figure 5. Cross-bedded quartzite near Chickmagalur, Bababudan belt.

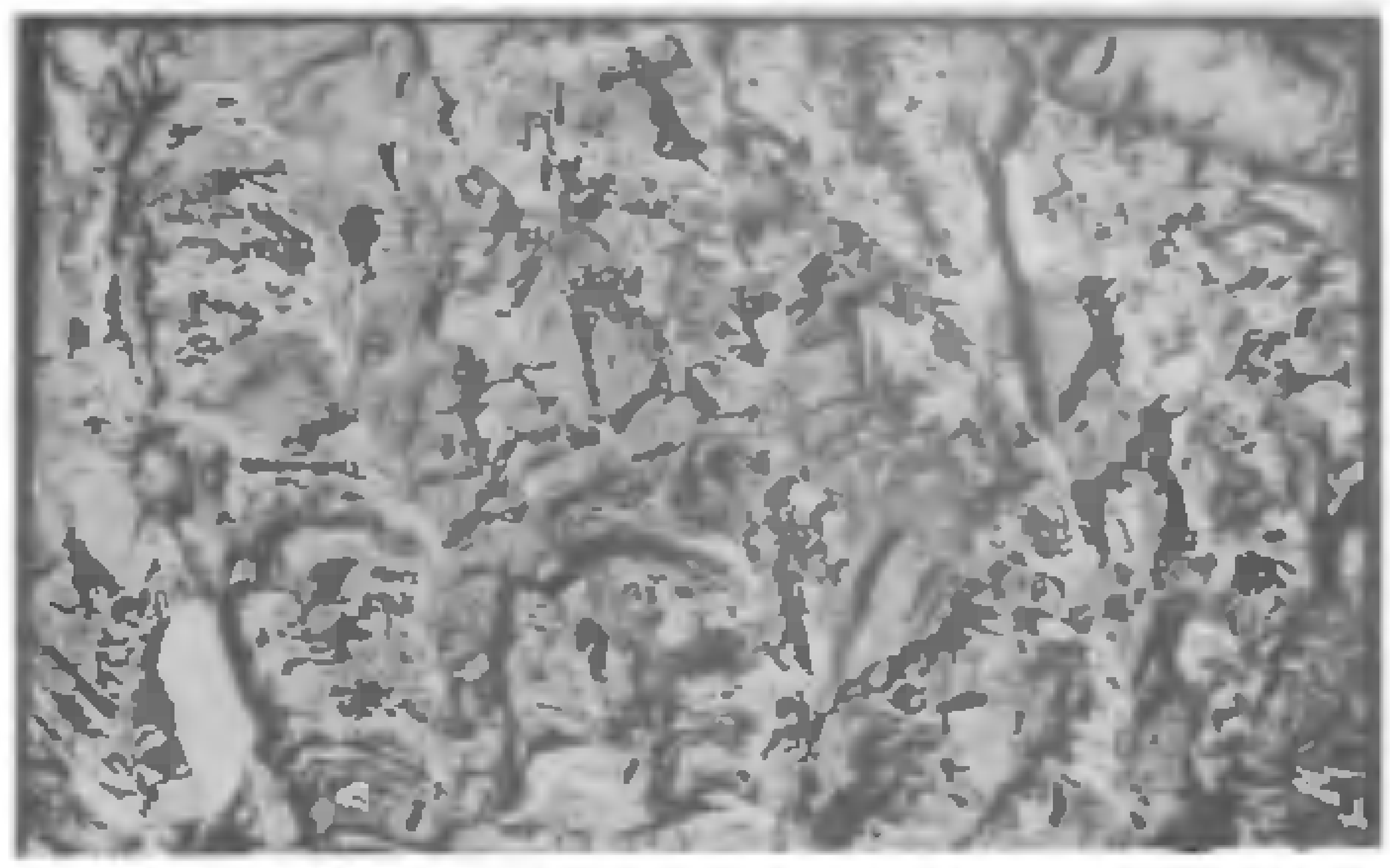

Figure 6. Stromatolitic cherty dolomite, Bhimasamudra, Chitradurga belt.

accumulated from a stable to a mobile environment is indicated in the Dharwar belts, unlike in the Baltic greenstone belts. The Dharwar supracrustal rocks, like the Lopian rocks, are metamorphosed to greenschist and amphibolite facies. A suite of high-grade metasedimentary and metaigneous rocks dominantly distributed in the southern part of the Dharwar province referred to as the Sargur Group is believed by some workers to be older than the Dharwar Group[17], whereas others consider it as higher grade equivalent of the rocks of the latter Group[21]. Gradual transition from low to high-grade supracrustal rocks as seen in the Belomorian zone described earlier is demonstrable in the Dharwar craton also[22], leading us to infer that the rocks of the Sargur Group, like the Saamian rocks, are greenstone belts metamorphosed to a higher grade[23].

It is also of interest to note that there are major differences in the metallogeny in the two terranes. Dharwar belts host gold deposits as well as small deposits of chromite and copper[24]. Extensive deposits of carbonates, iron and manganese are characteristic of the Dharwar belts[19]. By contrast, no significant gold deposit is as yet known from the Baltic greenstone belts. Manganese is absent in them and iron is restricted to one or two regions in western Karelia and central Kola peninsula. Uraniferous quartz pebble conglomerates and stromatolitic carbonate rocks as seen in the Dharwar belts do not appear before the middle Proterozoic (Jatulian) in the Baltic shield[25].

Conclusion

The foregoing differences in the sedimentary volcanic assemblages of the greenstone belts in the two terranes suggest that the variation in the styles of evolution of the greenstone belts is not only due to temporal causes, but is also due to spatial variation in the crust-mantle processes. This would imply that mantle heterogeneity was established quite early in the earth history. Apparently the sialic crust that preceded the formation of the Dharwar greenstone belts was thicker and stronger, capable of supporting stable zone volcanism, sedimentation and biological activity. By contrast the greenstone belts of Karelia in the Baltic shield might have evolved on thin, less stable sialic crust. Association of immature sediments with bimodal/polymodal volcanics in the Baltic shield indicates an island arc setting. By contrast, bimodal volcanic rocks associated with both mature and immature sediments in the Dharwar belts point to a back-arc environment.

That the Archaean greenstone belts evolved in a variety of tectonic environments and that no single model is universally applicable is demonstrated by the fact that (i) even in a single region such as the Baltic shield, greenstone belts comprise either bimodal and polymodal volcanic suites, and (ii) the volcanosedimentary and metallogenetic assemblages of the Dharwar and the Baltic shields show significant difference in characters.

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