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The genesis of Archaean chromitites from the Nuasahi and Sukinda massifs in the Singhbhum Craton, India

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Abstract

The chromitite deposits of the Nuasahi and Sukinda massifs are part of layered ultramafic bodies which occur within Archaean low-grade metamorphic rocks of the Iron Ore Group (IOG) in the Singhbhum Craton of the Indian Shield. The chromitite seams are interlayered with dunite, and associated with orthopyroxenite. Detailed electron microprobe study reveals very high *Mg*-numbers (0.66–0.82) and *Cr*-numbers (0.75–0.87) for chromite in massive chromitite from the seams, high Fo content (Fo_{92-95}) for olivine in dunite and high En content (En_{89-94}) for orthopyroxene in orthopyroxenite. Our study suggests that the original igneous compositions for these minerals are preserved in the respective monomineralic rocks and can be used to evaluate the primary magmatic petrogenesis of the rocks. The primitive compositions of the minerals in monomineralic rocks suggest high degree of partial melting of the source mantle during the Mesoarchaean. The parental magma from which the massive chromitites crystallized was of siliceous high-Mg basaltic or boninitic compositions, similar to the compositions of spatially associated chromite-bearing siliceous high-Mg basalts of the Iron Ore Group. The parental magma may have generated due to the interaction of a depleted mantle with a fluid-enriched melt possibly derived in response to the dehydration of a subducting slab. Monomineralic chromitite layers formed either in response to mixing of magmas or due to the suppression of silicate mineral crystallization in response to elevated H_2O concentrations in the parent magmas. The parental magmas that produced chromitites may have intruded into the volcano-sedimentary greenstone belts of a supra-subduction zone setting.

Keywords: Chromite; Chromitite; Peridotite; Subduction; Boninite; Archaean; Nuasahi (Boula); Sukinda; Singhbhum Craton; India

1. Introduction

Massive chromitites are found in a variety of mafic-ultramafic complexes of different tectonic settings. Stratiform chromitite layers occur in large layered intrusions such as the Bushveld and Stillwater Complexes, and in the crustal cumulate portions of ophiolite complexes. Discordant chromitite bodies are found in the lower portions of ophiolites that are thought to represent formation in the upper mantle. Archaean chromite deposits and the associated ultramafic-mafic rocks are found in different geological environments (e.g. Stowe, 1994) and are compositionally distinctive, suggesting derivation from various parental magma types (Rollinson, 1995a). Archaean chromite deposits are commonly found as either stratiform bodies that are interlayered with anorthosite in tonalite gneiss terrane (e.g. Fiskenasset layered intrusion in southern West Greenland, Rollinson et al., 2002),

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or as deformed bodies hosted by serpentinized peridotites in greenstone belts (e.g. Shurugwi greenstone belt in Zimbabwe, Stowe, 1997). One of the principal controls on chromite chemistry is parental melt compositions that vary in different tectonic settings, consequently chromite is a good indicator of the magmatic environment (e.g. Irvine, 1967; Dick and Bullen, 1984; Roeder, 1994; Kamenetsky et al., 2001). However, the compositions of chromite can be modified during cooling at the subsolidus stage and during metamorphism (e.g. Irvine, 1967; Jackson, 1969; Evans and Frost, 1975; Eales and Reynolds, 1986; Barnes, 2000). Therefore, petrological inferences based on chromite compositions require that the liquidus chromite composition be recovered (Rollinson, 1995b). In this paper we utilize primary chromite compositions to evaluate parent magma compositions and infer the tectonic setting of the Archaean chromitites in eastern India.

The Singhbhum Craton in eastern India is one of four significant cratonic nuclei in the Indian Shield (Fig. 1) (Radhakrishna and Naqvi, 1986; Saha, 1994), which contains several chromitite-bearing layered ultramafic bodies within Archaean greenstone belts (Acharyya, 1993; Mondal et al., 2002). The ultramafic rocks are found within supracrustal rocks of the Iron Ore Group mainly in the Nuasahi and Sukinda areas of Orissa state and the Roro-Jojohatu area of Bihar state (Srinivasachari, 1974; Mukhopadhyay and Dutta, 1983; Basu et al., 1997). Previous researchers interpreted the chromite deposits in the Nuasahi and Sukinda massifs either to be cumulates similar to those in large layered complexes such as the Bushveld Complex or mantle rocks similar to those in Alpine type peridotites or ophiolites (e.g. Banerjee, 1972; Chakraborty and Chakraborty, 1984; Page et al., 1985; Varma, 1986; Pal and Mitra, 2004). However, these studies were based on limited chromite and platinum-group element (PGE) data, and questions still remain with respect to origin of the chromitites and their host rocks, their tectonic settings and their broader significance with respect to Archaean crustal evolution. The Nuasahi and Sukinda massifs are of particular interest because they are the most significant chromite-bearing ultramafic bodies of the Archaean greenstone belts in the Indian Shield. The chromite ores account for ≈98% of the total resources in India and ≈2.5% of world resources. The chromitite bodies can be traced for several kilometers along strike and are well exposed in open-cut and underground workings. In addition, gabbro-breccia hosted PGE-mineralization is found in association with chromites in both the Nuasahi and Sukinda massifs. A better understanding of the tectonic setting in which the chromitites formed will be particularly valuable for future platinum exploration in the Archaean greenstone belts.

2. Regional geology

The four Archaean cratonic nuclei of the Indian Shield are the Dharwar, Bastar, and Singhbhum Cratons in the southern block and the Bundelkhand Craton in the northern block (Fig. 1, inset). The eastern part of the Indian Shield is known as the Singhbhum-North Orissa Province (Mukhopadhyay, 1988; Saha, 1994) and is composed of a high-grade metamorphic terrain known as the Chhotanagpur Craton to the north and a granite-greenstone terrain known as the Singhbhum Craton to the south (Fig. 1). The latter consists principally of (1) supracrustal rocks of the Older Metamorphic Group (OMG), and tonalitic rocks of the Older Metamorphic Tonalitic Gneiss (OMTG), (2) several granitoid batholiths (e.g. Singhbhum granite, Nilgiri granite, Bonai granite, Mayurbhanj granite), and (3) supracrustal rocks of the Iron Ore Group (IOG) greenstone sequences (Fig. 1; Table 1).

The Singhbhum Craton has a complex history of tectonic evolution through repeated extension and compression associated with sedimentation and magmatism from early Archaean to Proterozoic (Saha, 1994; Majumder et al., 2000). The Singhbhum Craton is bounded to the north by the Singhbhum shear zone (200 km long) and by the Sukinda thrust to the south. The Singhbhum granite is the largest composite batholith in the craton and has been divided into two phases: Granite of 'Type A' revealed a zircon U–Pb date of 3328 Ma (Mishra et al., 1999), whereas, Granite of 'Type B' has been dated at 3100 Ma by the Pb–Pb whole-rock isochron method (Saha, 1994). The oldest supracrustal suite in the Singhbhum Craton is the OMG with a zircon U–Pb age of 3.5 Ga (Mishra et al., 1999). The OMG consists of meta-igneous and metasedimentary rocks of amphibolite facies. It occurs as remnants along with the OMTG (zircon U–Pb date of 3.44 Ga; Mishra et al., 1999) within the granitic batholithic complex. A Sm–Nd whole-rock isochron age for the orthoamphibolites of the OMG yields an age of 3305 ± 60 Ma, which is considered to be the crystallization age of the protoliths (Sharma et al., 1994). The Archaean terrain experienced extensive mafic-ultramafic magmatism during the Proterozoic within the mobile belts (Fig. 1) such as the Dalma, Dhanjori, Simlipal, Jagannathpur and Malangtoli belts (Mukhopadhyay, 2001). A dolerite dyke swarm (Newer Dolerite, Table 1) intruded the Singhbhum Craton between 2500 and 950 Ma (Saha, 1994; Roy et al., 2005).