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Geochemical study of Archean gabbro-anorthositic rocks and magnetitite bodies of the Mayurbhanj Mafic Igneous Complex, Singhbhum Craton, India: Implications for origin of base metal sulfide mineralization

Abstract

The Mesoarchean Mayurbhanj Complex of the Singhbhum Craton contains magmatic Fe-Ti-V rich oxide ore deposits within a gabbro-norite-anorthosite suite of rocks. The immediate country rocks of the mafic complex belong to the Early Archean Iron Ore Group supracrustal rocks of the Gorumahishani - Badampahar greenstone belt and ~3.1Ga granite plutons. The gabbro-noritic rocks of the Mayurbhanj Complex (Betjharan section) consist of plagioclase (An_{26-69}), clinopyroxene ($En_{42-54}Fs_{4-36}Wo_{22-42}$), and orthopyroxene ($En_{67-81}Fs_{15-28}Wo_{4-5}$) as cumulus phases with intercumulus Fe-Ti-oxides (magnetite and ilmenite) and sulfides (pyrite, pyrrhotite, chalcopyrite) as disseminated phases whereas, the gabbro-anorthositic rocks (Hatichhad section) contain cumulus plagioclase (An_{1-49}) and clinopyroxene ($En_{24-38}Fs_{31-49}Wo_{14-44}$) with magnetite and ilmenite in the intercumulus phases. The magnetitite ores consist of magnetite and titanomagnetite as cumulus phases with ilmenite as exsolved phases. Disseminated sulfides are mainly present along the grain boundaries of accessory Fe-Ti oxide grains, within interstitial spaces of silicate minerals, as inclusions within the silicate minerals and along altered fracture zones of the silicate host within the gabbro-norite. The mineral chemical study suggests the gabbroic rocks of the Mayurbhanj Complex are the products of fractionation of a Fe-Ti rich basaltic magma. Two pyroxene thermometry yields temperature of 1199°C - 956°C for the gabbro-norites and 1096° - 839°C for the gabbro-anorthosites which are close to the primary liquidus temperature of pyroxene from a fractionated basaltic magma. The intercumulus magnetite of the gabbro-norite and gabbro-

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anorthosite have high concentration of Cr (22301 - 67433 ppm), Ni (896 - 3880 ppm) and Cr_2O_3 (0.03 - 0.21 wt. %), V_2O_3 (0.73 - 1.19 wt. %) indicating early fractionation of the accessory magnetite in the gabbro-norite and gabbro-anorthsosite than the cumulus magnetite of the magnetitite layers. The lower concentration of V (30211 - 34608 ppm) in the accessory magnetite of the gabbro-noritic rocks than in the magnetitite (48534 - 64855 ppm) suggests partitioning of vanadium into clinopyroxene within these rocks. The co-existing magnetite and ilmenite pairs in gabbro-norite, gabbro-anorthosite and magnetitites have yielded a temperature range of 798°C - 330°C with fO_2 11.38 – 38.35 reflecting various stages of cooling and sub-solidus re-equilibration of the mineral phases under QFM±2 condition. The continuous fractionation of the parental basaltic magma leads to Fe and Ti enrichment in the magma, and separation of a Fe-Ti rich liquid from the basaltic magma. The residual silicate melt became Si-rich. The magnetitite layers were formed from the Fe-rich liquid. The *in-situ* trace element analyses of the oxide minerals indicate higher chalcophile element (Pb = 2 - 11 ppm, Zn = 6773 - 8139 ppm, Mo = 25 - 68 ppm) concentrations in accessory magnetites of the gabbro-noritic rocks implying equilibration with co-magmatic sulfide mineral assemblages. The partitioning behavior of HFSE (Zr, Hf, Ta, Nb) in the magnetite and ilmenite is mainly dependent on the Ti^{4+} content of the minerals. Pyrite is the most abundant sulfide minerals present within the gabbro-norites. The probable mechanism for the formation of the sulfide assemblage was decrease of FeO activity of the parental basaltic magma due to crystallization of magnetite that triggered the sulfide saturation and formation of an immiscible sulfide liquid. The *in-situ* major and trace element analysis suggest two varieties of sulfides - (i) pyrite grains surrounded by rim of Fe-oxide minerals, and show negative Ni anomaly in trace element pattern. These pyrite grains were formed after pyrrhotites which are magmatic in origin, and (ii) pyrite grains which have enrichment of Pb (27 - 3120 ppm), Ag (8 - 15 ppm), Bi

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(0.2 - 9 ppm), As (48 - 6561 ppm), and Sb (0.4 - 18 ppm) indicate hydrothermal alteration of primary magmatic pyrite grains.

The bulk-rock major and trace element data of the gabbro-norite-anorthosite rocks of the Mayurbhanj Complex supports more primitive geochemical character of the gabbro-norites from the Betjharan section than the gabbro-anorthosites of the Hatichhad section. The plots of CaO, Al_2O_3, (Na_2O+K_2O) vs. MgO suggest both pyroxene and plagioclase were controlling the formation of gabbro-norite, and plagioclase was the early crystallizing phase for the gabbro-anorthosite rocks. In the chondrite normalized REE plot depletion of HREE in the gabbro-anorthosites than the gabbro-norites is due to lower modes of clinopyroxene grains in the former. The bulk rock Sm-Nd isotope analysis yields an isochron age of 3022 ± 180 Ma for the gabbro-anorthositic rocks of the Mayurbhanj Complex. Enrichment in LILE, negative Nb, Ta and Ti anomalies with weak positive Zr and Hf anomalies indicate small degree of crustal contamination which is also indicated by the plots of various incompatible elements (Zr vs. TiO_2, La vs. Sm, Th vs. Yb and Zr/Sm vs. Nb/Ta) where the samples of the Mayurbhanj Complex show minor affinity towards the older crustal materials of the Singhbhum Craton. The parental Fe-Ti-rich basaltic magma of the gabbro-norite-anorthositic rocks were originated by partial melting of a metasomatized continental lithospheric mantle wedge in an active continental margin setting. The parental magma emplaced in the shallow crustal magma chamber where the gabbro-norite-anorthositic rocks and magnetitite layers were formed by fractional crystallization process. The parental Fe-Ti-rich basaltic magma was emplaced within the Early Archean TTG dominated continental crust (OMTG, SBG I, II). The contemporaneous granitic plutons were formed due to crustal reworking of these older TTG [SBG I, II, OMTG] rocks. The negative ε_{Nd} of the gabbroic rocks (-4.4±3.3) suggests overprinting of post-magmatic hydrothermal alteration upon the crustal contamination. Comparison with time-equivalent ultramafic-mafic magmatic events suggests that the ~3.1 Ga Mayurbhanj

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Complex represents an amalgamation phase of the supercontinent 'Ur'. The Mayurbhanj Complex together with the time equivalent Dhanjori Complex, Jagannathpur-Malangtoli ultramafic-mafic volcanics, Keshargaria mafic dyke swarm, Nuasahi-Sukinda ultramafic-mafic Complex of the Singhbhum Craton and the Sargur-Nuggihalli-Holenarsipur greenstone belt of the western Dharwar Craton represents a major component of the Ghatgaon Large Igneous Province which is part of a large scale global ultramafic-mafic event of that time forming the supercontinent 'Ur'.

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