Petrology and geochemistry of a suite of felsic orthogneisses and its enclaves from the northern part of the North Purulia Shear Zone: Implications for the crustal evolution of the east Indian Shield during the Proterozoic time

Index no. 71/18/Geol. Sc./25

Abstract

A suite of meta igneous rocks having mafic and felsic compositions from the least studied northern part of the North Purulia Shear Zone of the Chotanagpur Granite Gneiss Complex (CGGC) have been investigated. The migmatitic mafic granulite with layered to patchy leucosomes, the oldest lithocomponent of the studied area, occurs as enclaves within the migmatitic felsic orthogneisses. The internal fabric of the mafic granulite is discordant with and cut across by the gneissic fabric of the enclosing gneissic rocks. The migmatitic felsic orthogneisses are intruded by the protoliths of a suite of megacrystic metaporphyritic charnockite that grades to biotite gneiss (Ferroan granitoids). The metaporphyritic charnockite contains pods of migmatitic felsic gneiss, suggesting repeated felsic magmatism and deformation. The metaporphyritic charnockites are intruded by a suite of metamafic dykes.

Interpreting the field and petrological attributes, as well as observations from the modelling study, suggest that layered and patchy leucosomes in the mafic granulite were caused by dehydration melting of amphibole-bearing protolith at the culmination of high-pressure metamorphism (~13-14 kbar and 800-900 °C along a geothermal gradient of ~19°C/km,). Observed and predicted melt compositions suggest that the leucosomes that are presumed to be quenched melt have the composition of trondjhemite. This study, therefore, provides a viable mechanism for the formation of TTG (Tonalite-Trondjhemite-Granodiorite) suites. The sequence of reaction textures that variably replaced the granoblastic assemblage (garne+clonopyroxene+plagioclase+titanite) that developed at the culmination of metamorphism defines a steeply decompressive P-T path (~13 to7 kbar). The high-pressure metamorphism, the geometry of the retrograde P-T path and the inferred geothermal gradient of 19°C/km at the culmination of metamorphism are consistent with a clockwise (CW) retrograde P-T path that is common in a continent-continent collision setting. The mafic granulite of the studied area joins the regional high-pressure metamorphism in the CGGC, which is dated to be of Palaeoproterozoic age. A low proportion of leucosomes vis-a-vis extensive growth of amphibole throughout the mafic granulite and evidence from pseudosection are consistently suggestive of fluid infiltration-driven metamorphism that led to the formation of amphibole-rich selvedges and hydration of the mafic granulite.

The mafic granulite develops a rare occurrence of rod-like intergrowths of clinopyroxene-ilmenite that variably replace titanite at contact with porphyroblastic garnet. The garnet proximal to the clinopyroxene-ilmenite intergrowth is variably replaced with symplectic clinopyroxene-plagioclase or a rind of plagioclase. Textural modelling study suggests that the decomposition of garnet+titanite forms ilmenite-clinopyroxene intergrowth. The presence of small granules of halogen-rich apatite within the ilmenite-clinopyroxene is consistent with a fluid-mediated process. Thermodynamic modelling in the NCFMAST (+H_2O) system demonstrates that the clinopyroxene-ilmenite symplectite was formed during the tectonic exhumation of the host mafic granulites. Relative to Fe, Mg, and Ca, Ti was less *mobile, and its mobility was restricted within the confines of titanite being replaced by the clinopyroxene-ilmenite symplectite.*

The geochemistry of the migmatitic felsic gneiss suggests that the magmatic protolith of the rock had I-type granite affinity that is commonly seen in the continental arc setting. The porphyritic structure and relict igneous textures of metaporphyritic charnockite, that intruded the migmatitic felsic gneiss support that the protolith of the megacrystic rock was emplaced as magmatic charnockite. Geochemically, metaporphyritic charnockite and associated biotite gneiss are ferroan, calc-alkalic, and meta- to peraluminous in composition. Variations of major and certain trace elements of both rock types show a similar trend with increasing silica content and maficity. This feature is consistent with the well-studied A-type granitoids of different parts of CGGC. The petrological attributes of the two suites of rocks do not support the mobility of elements beyond a few mm. Open system phase equilibrium modelling in the NCKFMASHTO system suggests that fractional crystallisation is responsible for the observed geochemical trends, and is considered as the likely mechanism for the formation of protolith of the metaporphyritic rocks and the biotite gneiss. The modelling study under different P-T, a_{H2O}, *and* fO_2 *conditions suggests that the ambient aH2O and fractional crystallisation primarily controlled the stabilisation of orthopyroxene in the magmatic stage. Fractionation of anhydrous minerals, including orthopyroxene, increased the* aH_2O *of the melt and triggered the crystallisation of orthopyroxene-free biotite granitoid (the protolith of biotite gneiss).*

The petrological attributes of the migmatitic felsic gneiss suggest that the dominant metamorphism (M2) culminated at 700-800 °C; 7.5-8 kbar along a geothermal gradient of 26-28 °C/km, which is distinctly hotter than the high-pressure metamorphism (M1) that are recorded in the mafic granulite enclaves. Frozen-in reaction textures support a steeply decompressive retrograde P-T path that can be traced to 600 °C, 6 kbar,. The ferroan granitoid suites and the metamafic dykes also share a similar retrograde P-T path. The geometry of the retrograde P-T path is consistent with a continent-continent collision event that superposed on the felsic rocks whose protoliths were formed in grossly different tectonic regimes. The mafic dyke that intruded all the felsic orthogneisses has escaped M2 high-grade metamorphism but bears the impress of amphibolite facies (M3) metamorphism and deformation. Integrating the inputs from the studied area with the published information, it is demonstrated that the magmatic and metamorphism imprints in the CGGC happened in response to the formation and breakup of the Proterozoic supercontinental cycles.

Sondipta Chatterjee
17/01/2024

Dr. Pulak Sengupta
Professor
Dept. of Geological Sciences

17.01.2024

Dr. Sanjoy Sanyal
Professor
Dept. of
Sciences
India