ARCHAEAN CARBONATE ROCKS (CARBONATITES?) FROM BORRA REGION IN THE EASTERN GHATS MOBILE BELT, INDIA

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ABSTRACT

The Borra region in the Eastern Ghats is known for the occurrence of phlogopite in the carbonate rocks. These rocks are associated with khondalites and charnockites of Archaean age, and their interbedded and gradational relationship and refolded nature indicate that the khondalite group of metasediments, garnet-sillimanite gneisses, quartzites and carbonate rocks, have undergone the same deformation, and are derived from pelites and associated marly clays and marls. The zoning of calc-granulites and diopsidites around calcite marble (dolamitic limestone) within the garnet–sillimanite gneisses suggests that pelites grade laterally into impure and pure calcite marbles. The migmatic features in sillimanite gneisses, calc-granulites and diopsidites and also the remarkably banded structures in the calcite marbles attest the widespread metamorphic differentiation process in the granulite belt.

It is recognized that the mobility of calcite is more pronounced from the limbs portions into the crestal part of anticline (F_2 shear fold) and has further led to the thickening and diapiric rise of the massive carbonate rock due to refolding (F_3) in the Eastern Ghats. The intrusive nature of Borra carbonate rocks is earlier reported due to the rheomorphic behaviour of calcite, updoming the upper horizons of khondalite metasediments.

INTRODUCTION

The Borra region in Visakhapatnam District, Andhra Pradesh forms a part of the Eastern Ghats and has attained geological importance for the occurrence of phlagopite mica in the carbonate rocks. The spectacular caves with the development of stalactites and stalagmites in this terrain are of tourist attraction. Earlier work[1] carried out in the Borra region is related to geology, phlogopite mineralization and origin of the carbonate rocks. The association of pyroxenites, syenites (?) and calcite marbles (mixed calcite-dolamite rocks of dolomitic limestone nature) and the field relationships have led some of the geologists to recognize them as carbonatite intrusions in the Eastern Ghats mobile belt. Barium feldspars[2], mica of eastonite composition[3], spinel–phlogopite diopsidites[4] and phlogopite–apatite occurrences[5] were described by a few investigators and assigned them to be the skarn products.

Detailed field observations, petrographic studies and mineral assemblages have been considered in arriving at the evolution of Borra carbonate rocks.

GEOLOGY AND STRUCTURE

The rock types in the area include khondalites (garnet–sillimanite gneisses, quartzites, calc-granulites, diopsidites, scapolite–diopside gneisses, calcite marbles) and charnockites (hypersthene granitic rocks) belonging to the granulite grade metamorphism. The repetition of the khondalitic and charnockitic rocks in the Eastern Ghats is due to the tight isoclinal folds present in the mobile belt. An overturned anticline (figure 1) is recognized based on the general attitude of the beds and strike and dip directions of foliations. The present studies on the Landsat imagery reveal that the Borra anticline is part of a doubly plunging anticline around Anantagiri

The calcite marbles frequently occur as minor patches and bands, and are interbedded with the garnet–sillimanite gneisses. The major calcite marble unit, in an extensive scale, is exposed around Borra and bordered by calc-granulites and diopsidites. The ubiquitous occurrence of garnet–sillimanite gneisses as layers and lenses within the marbles and vice versa indicate that these litho-units are gradational

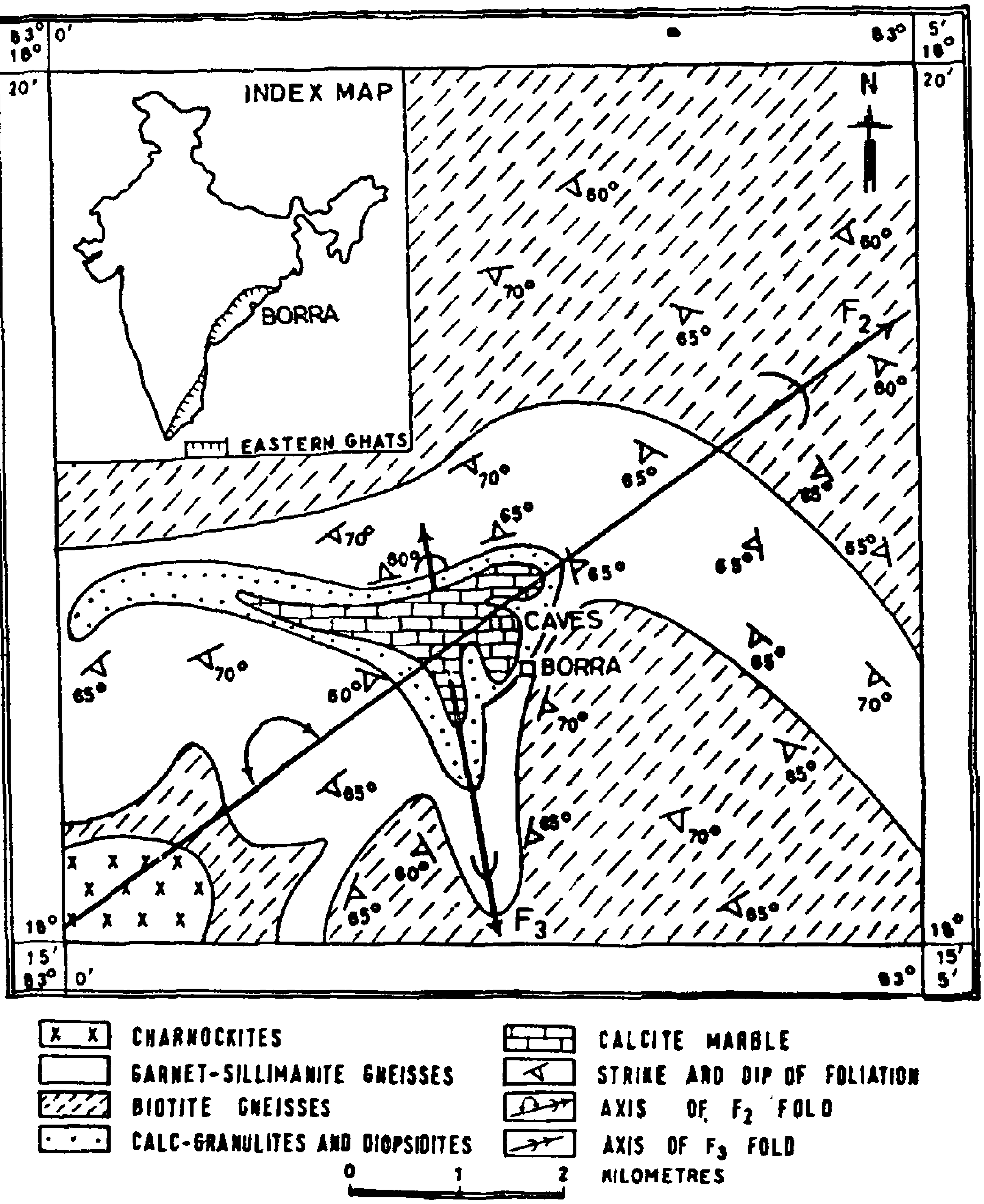


Figure 1. Geological map of Borra area, Visakhapatnam District, Andhra Pradesh.

and confirm the metasedimentary sequence. The refolded nature of the migmatized calc-granulites, diopsidites and garnet–sillimanite gneisses indicates that these metasediments have suffered the same deformation. The early deformation (F_1) in the khondalites has affected lithological layering[6] and the major structures (asymmetrical to isoclinal folds) are formed during the F_2 shear folding in a regional way giving rise to dominant NE–SW trend. The superimposed NW–SE trend, due to refolding has resulted in open, upright SE plunging folds (F_3), often resulting in domal structures which could be partly due to the interference of F_2 and F_3 folds.

LITHOLOGY AND PETROGRAPHY

The granulite grade mineral assemblages: garnet-sillimanite–orthoclase–quartz in the paragneisses, khondalites and diopside–spinel–phlogopite–plagioclase (mostly scapolitized)–orthoclase–calcite in the calc-granulites and diopsidites and the gradational and spatial relationship of calcareous rocks within the paragneisses indicate that these rocks are formed from marls, marly clays associated with pelites in the Eastern Ghats. The overall zoned feature of calc-granulites and diopsidites around the calcite marbles suggests that pelites grade laterally into impure and pure calcite marbles and retained original sedimentary facies variations. However, the migmatitic impression in the form of pegmatites made of orthoclase and quartz, garnet and sillimanite layers in the khondalites, diopside–phlogopite–scapolite and calcite in the calc-granulites and diopside–phlogopite–orthoclase and scapolite in the diopsidites is related to the early deformation leading to the segregation banding due to metamorphic differentiation. The calcite marbles free of impurities confined to the inner zone in the carbonate rocks also show signs of migmatization in the mode of rhythemic bands of dolomites and calcites. Agmatite-like structures exhibited by dolomite in the coarse crystalline calcites are not uncommon.

The white dolomites are medium-grained and contain mosaic of dolomite with accessory calcite localized in the intergranular spaces (figure 2). The pure coarse crystalline calcites occur in shades of white, yellow and blue and are characteristic with rhombohedral cleavage (figure 3). Diopside ± olivine, phlogopite and apatite crystals are occasionally embedded in the calcites at various places. X-ray studies of dolomites and calcites (figure 4) support the petrographic observations.

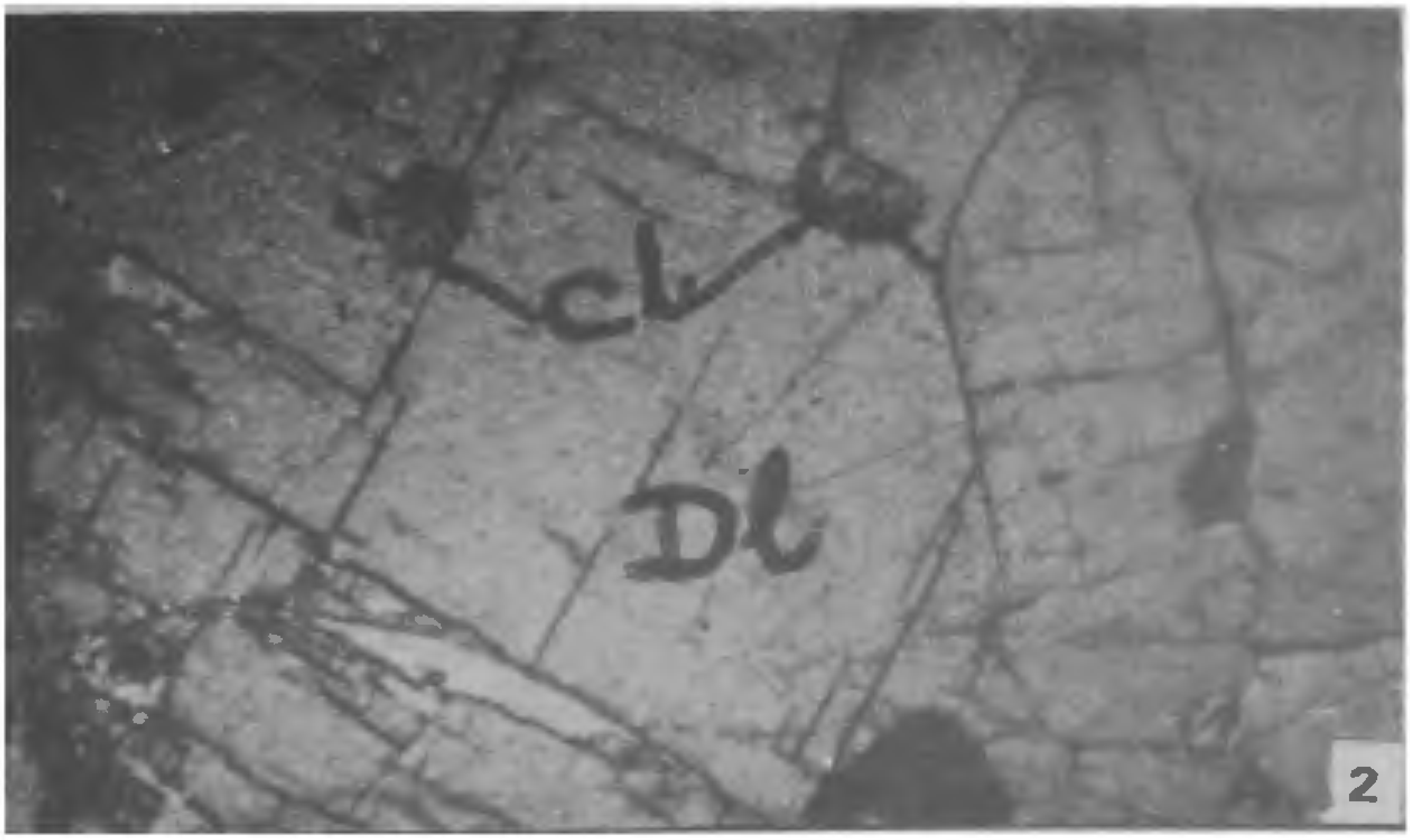
TECTONICS AND MOBILITY OF CALCITE

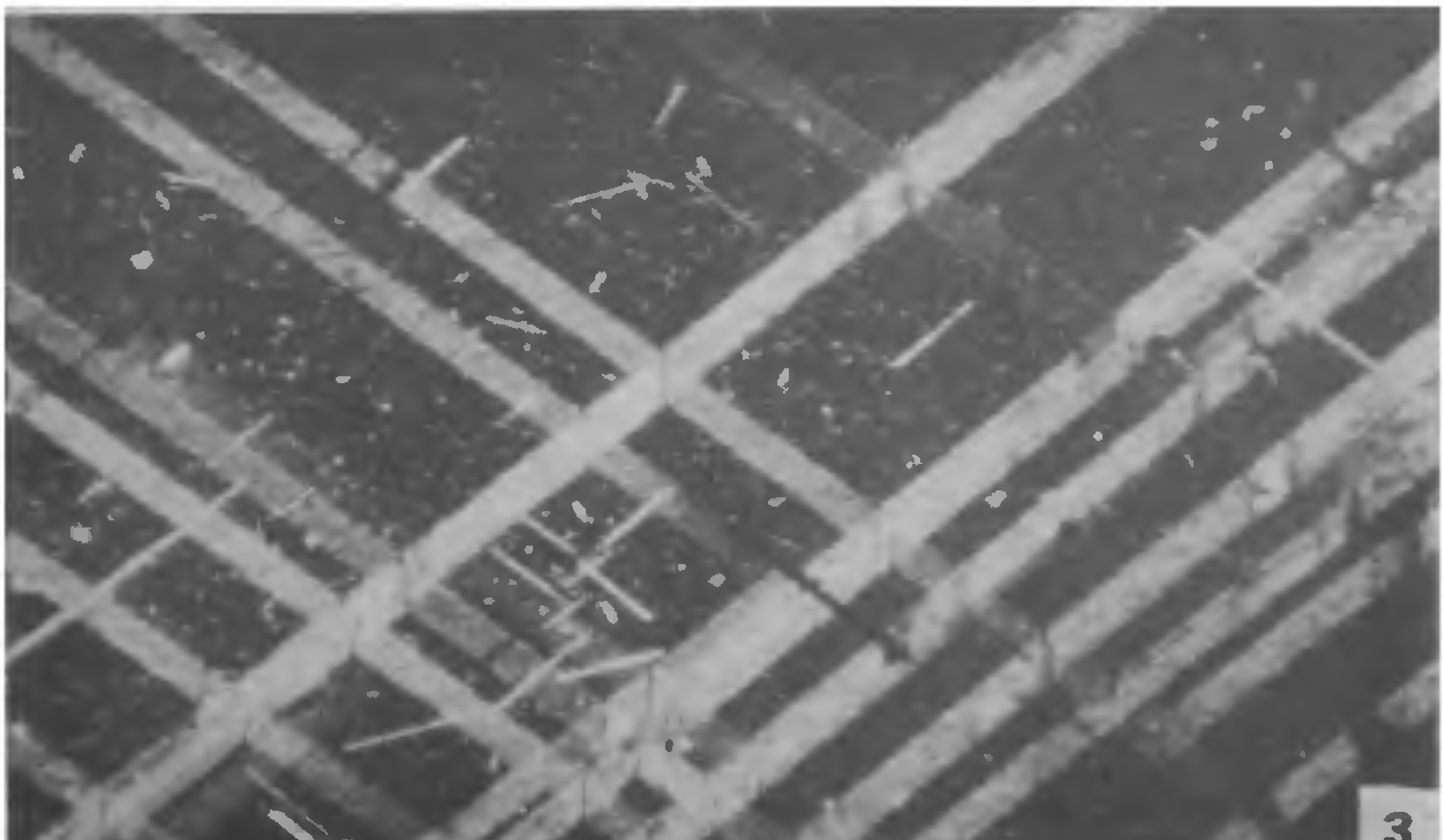
It is known that in the regionally deformed and metamorphosed Precambrian terrains, granites and associated mafic volcanics and/or igneous rocks are subjected to migmatization and palingenesis and evolved into granitic batholiths due to granite tectonics. The structure, nature and massiveness of the formations and metamorphic conditions have played an important role in such regional geologic processes. Moreover, the incompetent litho-units between the competent formations are rendered plastic resulting in significant structures like boudins, dragfolds and salt diapirs. The thickening of such plastic units in the hinge portions of folds witnessed the mobility and migration from the flanks. Similarly the calcite being more plastic than the associated dolomites, calc-granulites and sillimanite gneisses, has attained rheomorphic state. The enclaves or caught up patches of calc-granulites, diopsidites and dolomites in the remobilized coarse crystalline calcites are of usual occurrence and the dyke-like structures of calcite marbles are very scarce. Buckle folding at an early stage of deformation might have initiated the mobility of the calcite but is more pronounced from the limbs portions into the crestal part of the anticline developed due to shear folding (F_2). This has led to further thickening and rise of the entire carbonate mass to a considerable degree in promoting domal upwarp around Borra (figure 1) due to refolding (F_3). The occurrence of a depression within the Borra dome is related to the stretching of the dome in the central part and corroborates the overall mechanism of domal upwarps characterized by apical graben development. The granitic intrusions accompanying such a structure could have promoted the formation of skarns[5] in the carbonate rocks giving rise to apatite and second generation phlogopite.

DISCUSSION

The carbonatites of Tamil Nadu in the high grade granulite belt contain rare earth minerals[7]: Pyrochlore, cubic fergusonite, eschynite, chevkinite, thorite and sphene, and are emplaced in the deep faults during 750 m.y. age. The Borra crystalline limestones are considered to be the oldest (1490 m.y. age) carbonatite intrusions in the Precambrian terrain[1] and are devoid of radioactive minerals. The hyalophane–phlogopite–apatite–salite assemblage characteristic of skarn deposits and variations in mica composition from phlogopite to eastonite in the Borra region are reported[2, 3]. The spinel–phlogopite diopsidites and phlogopite–apatite occurrences[4, 5] are related to widespread *granitic/syenitic* contamination with dolomitic limestones in the Eastern Ghats. In view of the controversy of carbonatite versus skarn processes, REE geochemistry is considered besides the geological set-up in understanding the origin. The ratio of Σ ppm La-Lu/Σ ppm Gd-Lu, Y from Borra crystalline calcites varies from 1.13 to 1.30[8] and is nearer to the sedimentary limestones (1.65 – from Russian platform) rather than the carbonatites (7.10) as reported elsewhere.

The geological environment, tectonic features, aluminous-rich nature of clinopyroxenes–salite to





Figures 2 and 3. **2.** Photomicrograph showing a mosaic of dolomite (Dl) crystals along with a few inclusions of calcite (Cl) (identified by alizorian red staining) in the intergranular spaces (plane polarized light × 60); and **3.** photomicrograph showing deformation lamalle of calcite (crossed nicols × 60).

ferrosalite composition (2–7 wt% Al_2O_3) and phlogopite mica (15–28 wt% Al_2O_3) and the typical mineral assemblage: spinel-diopside-phlogopite, characteristic of metamorphosed impure calcareous dolomitic and marly sediments, preclude the possibility of carbonatite intrusions near Borra in the Eastern Ghats mobile belt.

Though significant differences in metamorphic temperatures and pressures from one area to the other are expected due to water pressure and fluid composition, the khondalites in charnockitic region, in general, are estimated[9] to have the P-T range 6–10 k bar and in the temperature range 800 855 C. The 3,000 m.y. age for the khondalites in granulite

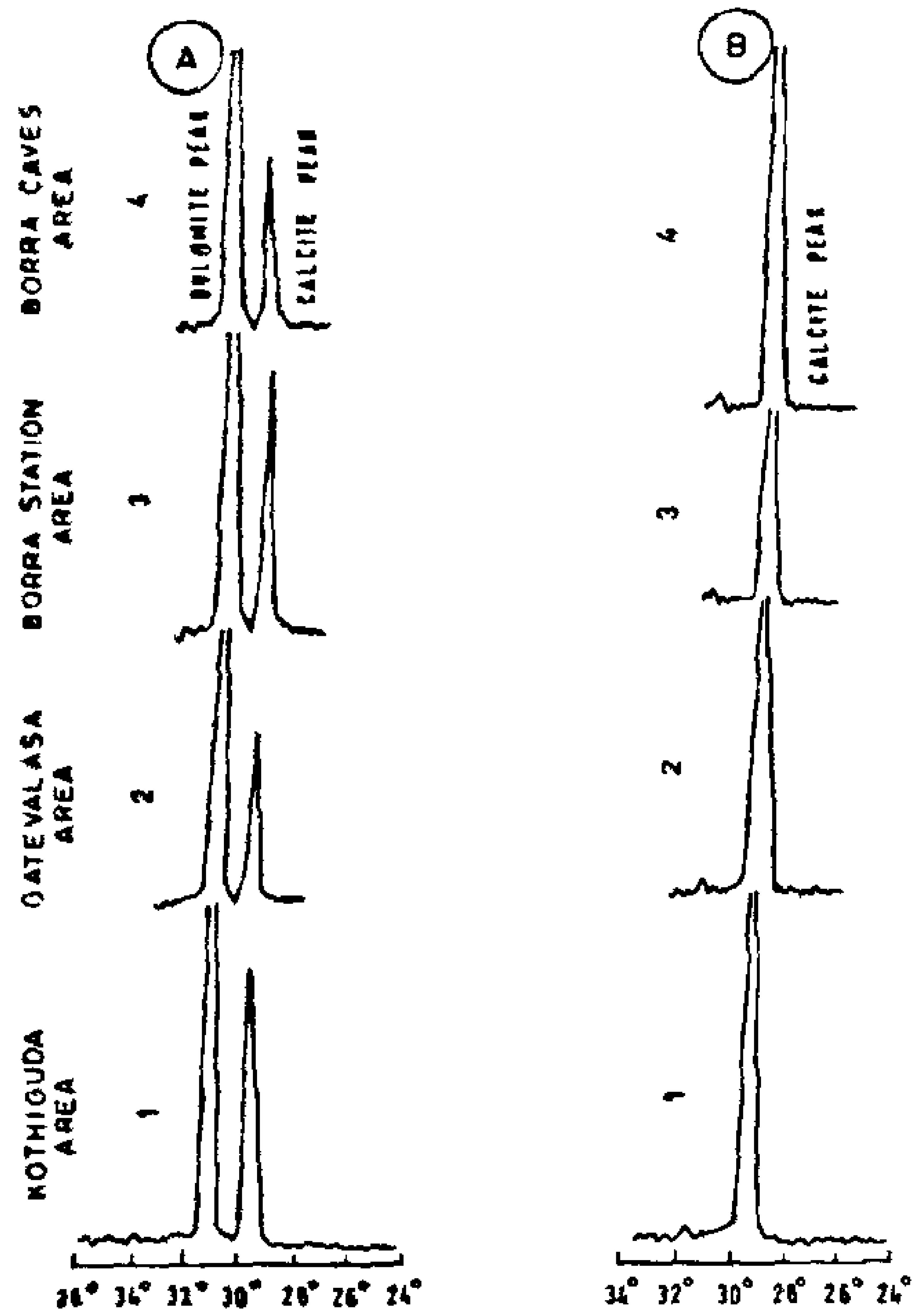


Figure 4. X-ray diffraction patterns of carbonate rocks: (A) Dolomites, and (B) crystalline calcites adjacent to each other from Borra area.

grade belt of Orissa and Andhra Pradesh[10] supports the hypothesis that the aggilaceous, areaneous and calcareous sediments were deposited much before 3000 m.y. and subsequently involved in three stages of deformation and metamorphism. The phlogopite age (1490 m.y) from Borra[11] corresponds with the 1600 m.y. episode of the Eastern Ghats orogeny[12] and indicates that the Archaean calcite marbles associated with the phlogopite-bearing calc-granulites and diopsidites, are successively remobilized and recrystallized. The rheomorphic behaviour of calcites, updoming the upper horizons of khondalite metasediments, coupled with the structural dome due to the interference of folds has resulted in an apparent intrusive nature.

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1. Ramam, P. K. and Viswanathan, T. V., *J. Geol. Soc. India*, 1977, **18**, 605.
2. Rao, A. T., *Proc. 3rd Indian Geol. Congr., Poona*, 1980, p. 183.
3. Rao, A. T. and Prabhakara Rao, P., *Rocks Miner.*, 1980, **55**, 210.
4. Rao, A. T. and Narendra, K., *Indian J. Geochem.*, 1983, **1**, 3.
5. Rao, A. T. and Narendra, K., *Indian Miner.*, 1986, **40**, 86.
6. Halden, N. M., Bowes, D. R. and Dash, B., *Trans. R. Soc. Edinburgh Earth Sci.*, 1982, **73**, 109.
7. Semenov, E. I., Upendran, R. and Subramanian, V., *J. Geol. Soc. India*, 1978, **19**, 550.
8. Rao, A. T. and Narendra, K., *Indian J. Geochem.*, 1987, **5** (in press).
9. Grew, E. S., *J. Geol. Soc. India*, 1982, **23**, 469.
10. Perraju, P., Kovach, A. and Svingor, E., *J. Geol. Soc. India*, 1979, **20**, 290.
11. Venkata Subramanian, V. S. and Krishnan, R. S., *Proc. Nat. Inst. Sci. India*, 1960, **A26**, Suppl. II, 89.
12. Holmes, A., *Proc. Geol. Assoc., Canada*, 1955, **7**, 81.