Field and Petrographic studies on the Zaffergadh granitoids, Eastern Dharwar Craton, Southern India

L. Rajashekar, K. Sreenu
Department of Geology, Osmania University, Hyderabad-500007

***Abstract*— The Eastern Dharwar Craton (EDC) is composed of numerous granitoids from the Late Neoarchean to Paleoproterozoic eras, the origin of which remains uncertain. The Zaffergadh granitoids within the Eastern Dharwar Craton (EDC) are the subject of a petrological analysis in this study. The field observations, concise microscopic analyses of Zaffergadh granitoids, and exhaustive microstructural assessments demonstrate a substantial divergence from the igneous magmatic textures of origin to the modified microstructures. The Zaffergadh granitoids under investigation are identified by their distinct gneissic and colossal characteristics. The mineralogy of Zaffergadh granitoids is primarily composed of K-feldspar, plagioclase, and quartz, with significant amounts of mafic minerals, including biotite and amphibole. The orthoclase and albite minerals exhibit a distinctive perthitic texture. The study area has observed significant characteristics of the poikilitic nature of microcline and its replacement by plagioclase. The results suggest that the rocks have experienced metamorphism and deformation.**

I. INTRODUCTION

The complex relationship between magma emplacement and deformation during regional shortening is a result of the challenges associated with identifying melt-related deformation structures and textures, as well as the potentially unclear connection between regional structures and plutons [1–3]. Furthermore, the analysis of these rocks in their original condition is complicate by the concealed influences of post-emplacement deformation and metamorphism on magmatic deformation fabrics in substantially altered terrains. In the southern Indian Shield, the Eastern Dharwar Craton (EDC) is composed of a variety of igneous materials, the majority of which date back to the Neoarchean era [4–6]. The deformation of partially crystallized granitoid magmas is crucial for the understanding of rheology, magma dynamics, emplacement mechanisms, ambient tectonic stress conditions, and associated processes within the magma chamber [7,8]. Numerous deformational processes may contribute to the deformation of partially solidified magma, as evidenced by numerous field observations and petrographic investigations [9,10]. These consist of suspension flow, granular flow, contact melting, melt ejection by filter pressing, microscale shear zone nucleation, and crystal plasticity [8,11]. Our ongoing investigation of granitoids from the Eastern Dharwar Craton has revealed a diverse array of microstructures that are linked to magmatic processes and deformation. The objective of this investigation is to investigate the grain-scale characteristics of the Zaffergadh granitoids, including hydrothermal alteration microstructures that are critical to the magmatic history of the granitoids, as well as the timeline of magmatic to sub-magmatic deformation. These characteristics range from magmatic to deformation-related structures.

II. GEOLOGICAL CONTEXT

The Dharwar Craton of the Indian Shield is comprised of the Eastern and Western Dharwar cratons (Fig. 1), which exhibit significant differences in basement age, characteristics, lithology, prevalence of greenstone belts, crustal thickness, and metamorphic intensity [12,13]. Moreover, the Western Dharwar Craton is deficient in alkaline magmatism when contrasted with its eastern counterpart. The Chitradurga shear zone, which is the prominent mylonitic zone along the eastern margin of the Chitradurga greenstone belt, is the point at which the two blocks are knitted together (Fig. 1) [14]. The Dharwar Craton's Precambrian lithologies are characterized by Archean tonalite–trondhjemite–granodiorite (TTG)-type gneisses, which are interspersed with two generations of greenstones and extensive calc-alkaline granitoids of more recent origin [13]. Granitoids, including granite gneiss, tonalite-trondhjemite-granodiorite (TTG), and syeno-monzogranites, are present in the northeastern region of the Eastern Dharwar Craton in southern India.

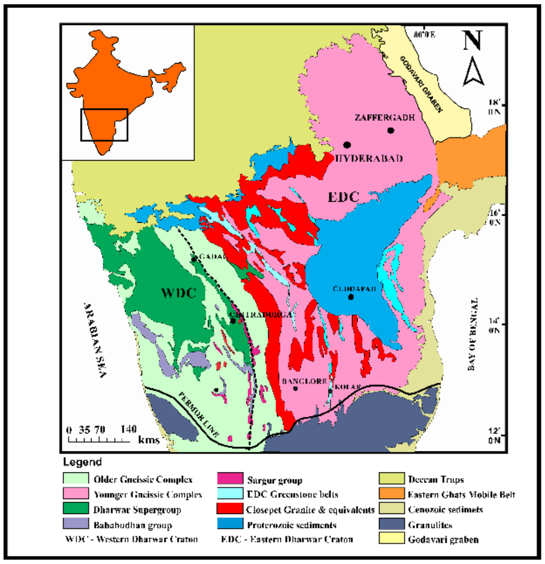

Fig. 1 Geological map of the Dharwar Craton (after Chardon et al. 2008).

These granitoids are accompanied by their corresponding microgranular mafic enclaves and dykes [15–17]. The basement TTG rocks are dated to the middle to late Archean, as demonstrated by [4]. Subsequently, the Archean to Proterozoic granitic formations are distinguished by Closepet granite [18]. The origin of these granitoids continues to be a contentious issue due to the existence of varying scholarly perspectives. Granitoid magmas are primarily associated with intraplate, oceanic, and collisional or subduction rifting environments [12,19–21]. Granitic magmatism is the most compelling evidence for Earth's unique subduction zone magmatism, as it is the result of the hydrous melting of the mantle [22]. According to the majority of geologists, the Eastern Dharwar Craton's continental crust formation reached its zenith between 2.7 and 2.5 billion years ago [12,21]. The Archean crust corridor is defined by five lithotypes: (i) tonalite–trondhjemite–granodiorite (TTG), which is primarily produced in the initial stages; (ii) volcanic-sedimentary greenstone belt sequences; (iii) late-stage high-K biotite granitic intrusions; (iv) sanukitoids; and (v) minor hybrid granites [21,23–25]. In general, the linear configuration of the majority of schist belts in EDC (Gadwal schist belt, Paddavuru schist belt, Ghanpur schist belt, and Yerraballi schist belt). The Zaffergadh granites, which are situated within the Ghanpur schist band, are visible as isolated intrusions within the granite gneisses of the Peninsular Gneissic Complex (PGC-II) of EDC (Fig. 1).

III. FIELD RELATIONSHIP

The Zaffergadh granitoids are composed of granitoids that range from light gray to light pink in color (Fig. 2a,b). These minerals are characterized by equigranular hypidiomorphic textures and medium to coarse particle diameters. The granitoids, which range from light pink to grey, have coarse to medium textures and exhibit gradational to diffusive interactions with the basement and associated rock types. The coarse-grained granitoids exhibit a basic foliation of mafic minerals that is associated with early-crystallized K-feldspar and biotite (Fig. 2b). This region is characterized by the segregation of mafic minerals within felsic bands. The darker mineral bands, which exhibit platy or elongated morphology, are interspersed with the lighter bands. Furthermore, felsic mush flow was observed in granitoids that exhibited both brittle and ductile deformation, suggesting the introduction of source magma during the late to post-magmatic phases or advanced magma evolution (Fig. 2c,d).

IV. PETROGRAPHY

A coarse to medium-grained, hypidiomorphic texture is exhibited by the Zaffergadh granitoids. Plagioclase, quartz, amphibole, and microcline or orthoclase perthitic feldspar are the primary constituents, with biotite serving as a secondary component. The interleaving of magnetite with hematite layers is the defining characteristic of opaque phases. Apatite and calcite are notable accessory phases, as well as garnet, diamond-shaped sphene, zircon, and allanite. Zircon is acknowledged as an inclusion in K-feldspar perthite and mafic aggregates. Plagioclase demonstrates polysynthetic twinning and microfractures that are occupied by opaque minerals, quartz, and biotite (Fig. 3a). Finegrained biotite and opaque minerals are present in substantial plagioclase crystals, which are encircled by subhedral quartz crystals (Fig. 3a). Quartz granules were present in the microcline, which was encircled by subhedral minerals (Fig. 3b). Flow perthitic texture was occasionally observed in conjunction with quartz and plagioclase (Fig. 3c). The myrmekite texture is a result of the intergrowth between quartz and plagioclase (Fig. 3d), while plagioclase undergoes a transformation into sericite, which influences both ductile and brittle deformation through alteration (Fig. 3d). The presence of secondary plagioclase in these granitoids suggests that fluid activity has caused a change (Fig. 3d).

Fig. 2 Field photographs of Khammam granitoids: (a) light pink coarse-grained granite exhibits magmatic foliation. (b) the grey granite exposes alternate dark and felsic bands. (c) the granites having magmatic foliation with brittle deformation. (d) light pink granites shows ductile deformation features.

V. DISCUSSION

Granitic terrains are characterized by a high degree of diversity, which includes solid-state structures that are the result of deformation, exclusively magmatic foliations, and magmatic structures [26]. The Zaffergadh Granitoids are foliated by the surrounding granites, contain mafic magmatic enclaves, and exhibit moderate deformation. The alignment of mafic magmatic enclaves with the foliation suggests that magmatic flow occurred as magma globules (Fig. 2c). The granites that exhibit foliation indicate a magmatic flow mechanism (Fig. 2a,b). Fractures and elongation are observed in the granites (Fig. 2c,d), which suggests solid-state deformation. The

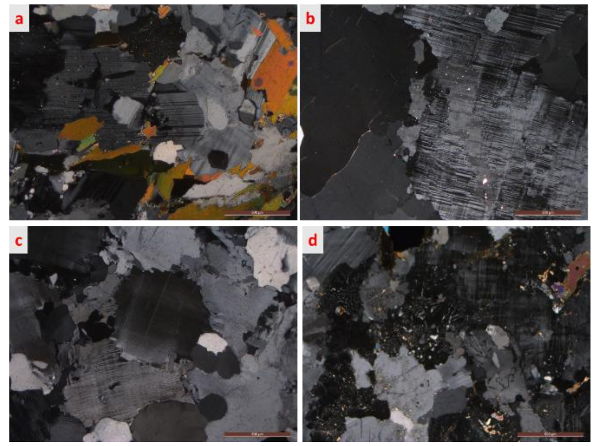

Fig. 3 Photomicrographs of Khammam granitoids: **(a)** twinned plagioclase and fractures filled by mafic mineral and subhedral quartz grains, (**b**) quartz grains hosted microcline, (**c**) flame perthite surrounded by recrystallized minerals, (d**)** intergrowth between quartz and plagioclase and plagioclase altered to sericite.

Zaffergadh granitoids are petrographically distinguished by medium to coarse-grained textures, which are characterized by both equigranular and inequigranular forms. In the solid state, plagioclase frequently exhibits distortion and is characterized by characteristic fissures and inclusions (Fig. 3a,c) [3,8,27]. The interaction of feldspar with fluid at sub-solidus temperatures is the cause of the coarse, incoherent, irregular, and hazy appearance of Perthite (Fig. 3c) [28,29]. This results in the substitution of albite for perthite at crystal margins or along fractures and cleavages during post-magmatic phases. K-feldspar is composed of subhedral quartz crystals and frequently exhibits a flaming perthite pattern (Fig. 3c). Solid-state deformation has been observed in flame perthite [30,31]. Diffuse deformation zones in perthite contain small anhedral crystals of quartz and albite. [32–36] have all indicated that the microstructures of this interstitial mineral assemblage, which exhibit myrmekite texture and subgrains in albite (Fig. 3d), underwent subsolidus ductile deformation at elevated temperatures.

VI. CONCLUSIONS

The Zaffergadh granitoids, which are situated on the northeastern margin of the Eastern Dharwar craton, demonstrate notable magmatic–solid-state flow characteristics. The Zaffergadh granitoids exhibit parallel foliation, which indicates a distinct alignment of feldspar and biotite, thereby supporting the magmatic flow process. The effects of solid-state deformation typically superimpose on the magmatic foliation. Additional evidence for solid-state deformation is provided by the petrographic characteristics, which include myrmekite textures and fractured and flow perthite formations. However, transitions between these states are anticipated to occur during magma cooling, particularly during regional deformation known as sub-magmatic. Evidence for the "end-member" conditions of magmatic and solid-state flow is frequently observed. This research suggests that deformation occurred in the newly formed crystals, crystal slurry, and ambient liquids during the transition from magmatic to sub-magmatic environments.

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