Summary [EN]

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Description :

Summary of my PhD thesis

Late-Archaean granitic magmatism : example of the Dharwar Craton (S.India) (Closepet granite and related intrusions)

Goals of the study

Most part of the continental crust formed during the Archaen (2.5 - 4.0 Ga). The primitive, archaean crust was made of TTG (tonalite-trondhjemite-granodiorite): Na-rich granitoids, produced by partial melting of hydrous basalt in the garnet stability field. The most likely formation context was in active subduction zones: as the Archaean Earth was hotter than the present, geothermal gradients were higher, thus allowing the partial melting of the subducted slab. The situation is reverse in modern times, and the subducted slad is dehydrated before reaching its solidus. Since the End of the Archaean, crustal production rates are low and the juvenile crust is no more TTG, but calc-alkali. This makes the Archaean-Proterozoic boundary a major time limit in Earth's history. Studying the magmatism at that time provides informations on how this transition occured, and on the crustal evolution during time. In most cratons, the end of the Archaean is marked by a period of intense crustal growth (granite emplacement) followed by a long period of geological inactivity. Granites emplacing at that time are neither true TTG, nor classical, modern calc-alkali granitoids. Instead, they are Mg- and K-rich granitoids, with REE nd other incompatible elements patterns similar to the TTG's. The Dharwar Craton of South India is the target of this study. The Eastern half of the craton is indeed made of a number of 2.6-2.5 Ga granitic plutons intruding an old (3.0 - 2.7 Ga) TTG basement. The largest of these granitic bodies, the Closepet granite, spans over 400 km long and 30 km wide. Geological mapping

The first part of this work was the drawing of a synthetic map of the granitic intrusions from the Eastern Dharwar Craton. While the Western Dharwar Craton was relatively well-known, no or few map depicted a proper picture of the late-Archaean magmatism in the Eastern Dharwar. Actually, most published map made no difference between older TTG and younger granites. The map presented here (fig. 1) is based on remote sensing (SPOT images interpretation), published data and field work (about 3 weeks).

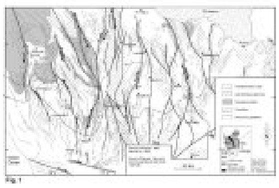

Fig. 1 : Geological map of the Dharwar craton. Bottom: Localisation in the Indian Peninsula. Main map: Lithologies and structures in the Dharwar craton. Note the marked opposition between the two parts of the craton. The Closepet granite is the large granitic body running North-South, from Ramanagaram to Pavagada and further North.West of Closepet, the map is drawn from published data (mainly H.Bouhallier's thesis, Rennes, 1995); East of Closepet, the map is drawn from SPOT images and field work.

Structural study of the Closepet granite

The Dharwar craton dispalys a natural cross-section in the Archaean crust, from deep structural levels (granulites) to the south, to shallow levels (greenschist facies) in the North. The Closepet granite crops out at all structural levels, and hence is an outstanding example to study granite emplacement mode depending on depth. Furthermore, conclusions on the structural context of the Closepet granite emplacement bring key informations to our understanding of the evolution of the Craton. Field work, structural analysis, anomaly of magnetic susceptibility and remote sensing were used together to describe the strain pattern in and around the Closepet granite, and propose an emplacement model: magmas formed in the crust and the mantle (see below) were collected in active shear zones ("root zone"). As they cristalized, transpressive tectonic activity pressed these magmas ("transfert zone") and expelled remaining liquids from the mush. The liquids were able to cross a rheological interface ("the gap"), rose to the upper crust and filled small, elliptic intrusions. The rest of the mush was unable to cross that interface and remained trapped below (fig. 2). This syntectonic emplacement history also points to the role of large scale horizontal movement (trnaspression along crustal-scale shear zones) in the Archaean.

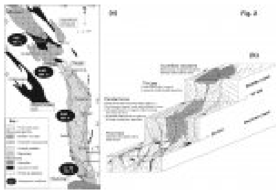

Fig. 2 : (a) : Simplified geological map of the Closepet granite, displaying the 4 zones described in the text. (b) : Sketch drawing of the relationships between deformation and granite emplacement, at different structural le

Geochemical modelling

A geochemical model of the formation of the Closepet granite has been built, using 8 major elements and about 20 trace elements, plus constrains from isotopic data, field work and petrography (fig. 3).

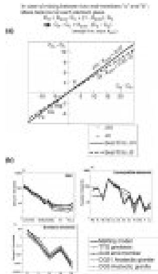

Fig. 3 : Two examples of geochemical modelling. Deux exemples de modélisation géochimique. (a) : "Mixing test" of Allègre and Fourcade (1981) applied to the dominant porphyritic granite of the Closepet. Points corresponding to each element plot along a straight line going to the origin, pointing to the importance of magma mixing in the petrogenetical story. (b) : The acid end-member of the mixing (see (a) above) can be modelled with partial melting of the Peninsular Gneisses. The melting model is in ecellent agreement with the acid end-member, and both are quite alike to the anatectic granites sampled.

On the basis of this study, the following model is proposed (fig. 4): mafic magma produced by partial melting of the mantle intruded a hot, gneissic continental crust. They underwent limited fractionnal crystalization, and simultaneously, due to the heat advection, the gneissic crust melted. Both anatectic and mantle-derived magma mixed, giving rise to a large petrographic diversity (monzonites to granites). The mantle that melted was enriched. The most likelmy cause of enrichment is interaction between peridotites, and "slab melts" (aprtial melts of the subducted, basaltic slab in an active subduction zone). These interactions produce both enriched (metasomatized) mantle, and hybridized magmas (Rapp et al., 2000).

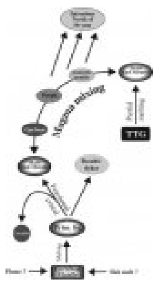

Fig.4: Summary of the geochemical model proposed for the Closepet granite

Geochemistry of EDC granites

It has been possible to propose a petrological and geochemical typology of EDC granites. Four main types have been described:

- "Slab melts" (TTG) and hybridized slab melts, similar to the "sanukitoids" described in most Archaean provinces; both types slightly predate the formation of the Closepet granite. Their trace elements contents confirm their genetic link with the Closepet granite (fig. 5).
- Anatectic granites, derived from the partial melting of either old (3.0 Ga) or newly accreted TTG
- Late, Closepet-like granites.

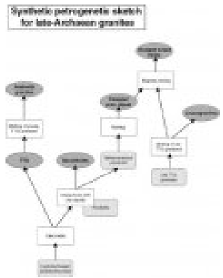

Fig. 5: Synthetic petrogenetic sketch for the different types of EDC granites.

Two geodynamical models have been proposed to account for this diversity. The first one proposes the impact of a mantle plume to account both for the mantle enrichment, and the heating. The second one interprets the geochemical features in term of subduction, followed by remelting of the mantle enriched during the subduction event; thermal effects similar to late-collisional processes would account for the mantle remelting.

Geochemical and geological arguments lead to prefer the second model.

The same types of granites (TTG, sanukitoids, Closepet and anatectic) are found in most Archaean provinces. This leads to propose a new evolutionary mechanism for the Archaean lithosphere: each Archaean craton underwent several similar evolution cycles (fig. 6), with a subduction stage (accretion of island arcs, with production of TTG and/or sanukitoid magmas), followed by a reworking stage (dome and basin tectonic, with LP/HT metamorphism and Closepet-like and anatectic granites). This cycle is followed by a period of geological inactivity (sedimentation of new greenstone belts). As the Earth progressively cooled during the Archaean, each cycle occured in a colder and colder environment. Hence, the slab melt / mantle wedge interactions increased during time. At the beginning of the Archaean, only TTG were formed; progressively, sanukitoids became more and more abundant; at the same time, this important interactions produced large amounts of enriched mantle, leading to the formation of "Closepet-like" granites. Finally, when the Earth was cold enough, melting of subducted slab became impossible (except in very specific situations). It is extremely likely that, at the end of the Archaean, mantle cooling was accelerated by global-scale effects (supercontinent formation ? mantle convection cell reorganization ?).

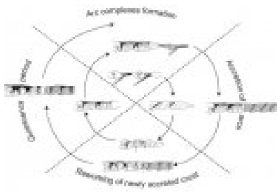

Fig.6: Geological and structural characteristics of Archaean cratons are best explained with a polycyclic evolution. Each cycle is made of a subduction stage, followed by arc accretion along transpressive shear zones. The newly accreted continent is reworked (post collisional episodes, with dome and basion tectonics and associated magmatism and metamorphism). A new cycle, at the border of the craton, can start, after a period of geological inactivity.