VOLCANISM AND INTRUSIONS OF THE DECCAN TRAPS, INDIA: GEOCHEMISTRY AND GEOCHRONOLOGY OF THE MAGMATIC ROCKS, GEODYNAMIC AND PALEOENVIRONMENTAL CONSEQUENCES

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Abstract

Large Igneous Provinces (LIPs) are build by the emplacement of large quantities of magma in a relatively short time. They cover vast areas and are mainly constituted by basic lavas.

During the last year, I focused my research on two important LIPs: the Deccan Traps (India), and the Central Atlantic Magmatic Province (CAMP). Deccan Traps formed about 66Ma and are linked to the Reunion hotspot and the northward migration of India. They cover the west-central India and consist of thick lava flows and intrusive complexes. The investigated area is located in the northern part of the Deccan Traps and consists of alkali-carbonatite bodies whose geochemical and geochronological characterization will provide more constraints about their origin. XRF analyses show a large compositional range which comprises both alkaline and tholeiitic series.

CAMP formed about 200Ma and it is connected to the opening of the Central Atlantic Ocean; the here studied Freetown Layered Complex is part of the CAMP and is a layered mafic intrusion that outcrops on the western coast of Sierra Leone (Africa). The comparison between previous LA-ICP-MS analyses and new Sr isotopic composition on plagioclases and clinopyroxenes separates support the hypothesis of a later formation of clinopyroxenes from a residual magma.

Introduction

Deccan Traps are one of the world’s largest continental flood basalt provinces. This province now covers more than 0.5 MKn², with an estimated original extent of about 1.5 MKn². It intruded the Archean crust at about 66 Ma, spanning the Cretaceous/Paleogene boundary; its age implies a possible relationship between it and the K/Pg mass extinction (Mahoney, 1988).

The most accepted model for the formation of Deccan Traps is that they were generated by a mantle plume, during the northward migration of India over the Reunion hotspot (Basu el al., 1993). Rocks are mainly constituted by nearly horizontal tholeiitic lava flows; the sequence reaches its maximum exposed thickness of 1700m in the Igatpuri area (in the western Gaths, W India) and thins toward east, because of the pre-Deccan topography (Mahoney, 1988). The pile has been divided into eleven formations and further divided into upper five formations (from bottom to top: Bushe, Lower and Upper Poladpur, Ambenali, Mahabaleshwar and Desur) and lower six formations (from bottom to top: Jawhar, Igatpuri, Neral, Thakurvadi, Bhimashankar and Khandala) on the basis of their chemical and isotopic compositions. Among the upper formations, the Ambenali fm. presents the highest εNd i=66Ma (+4 to +7) and the lowest 87Sr/86Sr (0.7038 to 0.7044), suggesting that it is the least contaminated formation. From its isotopic compositions other formations describe two trends: the Ambenali-Poladpur-Bushe trend points to high 87Sr/86Sr (0.7134 to 0.7202) suggesting a contamination with Archean crust; the Ambenali-Panhala-Mahabalshwar trend reaches low εNd i (+5.1 to -5.8) and very low (87Sr/86Sr) (0.704 to 0.7055) and thus is thought to have been contaminated either by an ancient granulitic crust or by an old continental lithospheric mantle; the large spread in Pb isotopic composition is consistent with mixing between Ambenali formation and at least two components. The composition of the lower formations is characterised by the presence of a common signature which has been contaminated with at least three different continental endmembers with variable Sr and Pb isotopic compositions (Peng et al., 1994).

Besides tholeiitic rocks, Deccan Traps are characterised by the presence of alkali-carbonatite bodies, which are the main topic of this research. Their relationship with the tholeiites will be constrained through a better determination of their age and mantle source, evaluating whether this can be the same as that of the tholeiites.

The investigated region is situated 400km North of Mumbai (W India) in Gujarat and Madhya Pradesh states and consists of three areas.
The largest area (≈ 1200 km$^2$) is the Chhota Udaipur sub-province (Gwalani et al., 1993) which has been divided into sectors based on their predominant lithology: 1) the Amba Dongar sector is characterised by a carbonatite-ring complex which intruded Cretaceous sediments (Bagh sandstone), the carbonatite-alkalic complex consists of an innermost ring of carbonatite breccia rimmed by calcio-carbonatite which is intruded by ferrocarbonatite plugs and dykes and cored by basalt (Simonetti et al., 1995); 2) the Siriwasan-Dugdha sector contains trachytic rocks and tinguaites; 3) the Phenai-Mata sector shows an association between alkaline rocks and a layered tholeiitic intrusion constituted by a layered gabbro associated with anorthosite, granophyre, nepheline syenite and dolerite (Sukheswala et al., 1973); 4) the Panwad-Kanwant sector is mainly characterized by syenite, phonolite, lamprophyre and tinguaites which form plugs and dykes striking ENE or WNW; 5) the Bakhatgarh-Phulmahal sector contains basic and ultrabasic dykes mostly with ENE trend, they consist of dolerites and picrite basalts.

In the same area a further division based on temporal succession of the lithology identifies five different suites: 1) Deccan Traps s.s. constituted by tholeiitic lava flows; 2) Phenai Mata complex which intrudes the first suite; 3) a main alkaline intrusive suite that consists of nephelinites, tephrites, phonolites, tinguaites and lamprophyres; 4) a trachytic suite of dikes and plugs; 5) a late basic-ultrabasic suite of dykes and plugs which increase eastward.

50km eastern of the Amba Dongar area, the Rajpipla area shows a similar succession with early tholeiites (lava flows) overlain by K-rich alkaline flows which constitute the main exposed sequence, in turn cut by late tholeiitic dykes (Krishnamurty et al., 1980). The Rajpipla alkaline suite has a maximum thickness of 200m in the north-eastern part and is composed by basaltic and trachybasaltic flows, with minor ankaramite and mugearite and is cut by masses of K-rhyolites.

Mount Pavagadh is the northernmost sampled area (50km NE of Phenai Mata) and consists of a 550m thick sequence of basaltic lavas overlain at the top by rhyolitic lavas with a thin layer of pitchstone.

The Central Atlantic Magmatic Province (CAMP) formed about 200Ma and is linked to the opening of the Atlantic Ocean. It formed as a contemporaneous event on four continents (North and South America, Europe and Africa) and covers an area of more than 10MKm$^2$.

The Freetown layered complex (FLC) is a tholeiitic mafic intrusion in Sierra Leone, west Africa dated at 193 Ma (Rb-Sr isochron age; Beckinsale et al., 1977). It may have been intruded as part of the CAMP during the break-up of Pangea. The FLC outcrops over a distance of 64x15 km and is about 7 km thick. The FLC can be divided into four zones (z-1, z-2, z-3, z-4) characterized by topographic expression and repetition of rock types (Chalokwu, 2001), which are mostly gabbroic and vary from olivine- to plagioclase-rich. The exposed part of z-1 is constituted by troctolites, olivine-gabbros, gabbros and anorthosites; z-2 is 1000m thick and composed by rhythmically layered gabbro, olivine-gabbro, anorthosite and gabbronorite; z-3 is the thickest one and consist of 1700m rhythmically layered lower zone, and 2000m of massive anorthosite-gabbro upper interval; z-4 is 1900m thick and is composed by gabbronorite and olivine-gabbro, less by troctolite.

**First year activity**

**Sampling**

Field activity has been carried out in January and February 2011 in India and it was focused mainly on the intrusive bodies, both complexes and dykes, in the three regions mentioned above.

At Amba Dongar the sampling was performed in a quarry and samples of carbonatites and basic dykes have been collected. At the Phenai Mata hill all the lithologies that form the region have been sampled with the addition of a gneiss, probably representative of the pre-Cambrian basement rocks. In the Sajwa area (north of Phenai Mata) trachytes and tinguaites have been sampled.

In the Panwad-Kanwant sector, dykes of different lithology were collected: phonolitic and basaltic dykes trending N50-N55 in the former, lamprophyre and basalt trending NW in the latter.

In the Bakhatgarh-Phulmahal sector basaltic and picritic dykes have been sampled and according to Gwalani et al. (1993), they belong to the late basic-ultrabasic suite.
Samples collected in the Rajpipla area consist of tholeiitic basalts (from active quarries), rhyolites, trachybasalts and mugearites, whereas on the Mount Pavagadh consist of picrites and pitchstones.

Samples preparation and analyses
63 samples have been collected. After the processing of samples (crushing, preparation of powders and preparation of tablets), major and trace element whole-rock concentrations were measured at the Università degli Studi di Napoli Federico II by X-ray fluorescence.

Given the different nature of the samples, plotting their compositions on a TAS diagram (total alkali vs. silica), they fall in different fields, covering a large range of compositions; they belong both to the alkalic and to the tholeiitic series. The majority of the alkeline rocks are potassic (Na₂O-K₂O<2 wt%).

Considering the SiO₂ content, the compositional range varies from 43 to 77 wt%, while the total alkali content varies from 1.4 wt% to 14.6 wt%; MgO ranges from 17 to near zero wt%.

Trace element analysis by ICP are planned on 40 selected samples, whereas isotopic compositions will be analysed on 30 selected samples, and, on this purpose, a careful handpicking is in progress, in order to separate the freshest portions of the samples. Furthermore, about 10 samples will be dated by ⁴⁰Ar/³⁹Ar methods.

Previous analyses on plagioclase (plg) and pyroxene crystals by LA-ICP-MS and electron microprobe on four samples of the FLC have shown a higher incompatible element content in the clinopyroxenes (cpx) of the z-1 compared to z-2, z-3 and z-4 crystals. z-1 clinopyroxenes seem to be also slightly enriched in incompatible elements (e.g., LREE) compared to plagioclase crystals from the same rock sample, i.e., these clinopyroxenes are in disequilibrium with the associated plagioclase and probably crystallized from a more enriched magma.

Handpicked plg and cpx separates of three samples (belonging to z-1, z-3 and z-4) were analysed for Sr isotopic composition in order to constrain the evidence for disequilibrium crystallization, comparing the result to whole-rock (wr) Sr isotopic compositions.

Cpx of z-1 and z-4 have a more radiogenic composition ((⁸⁷Sr/⁸⁶Sr)ᵢ=200Ma 0.704097 and 0.703809, respectively) compared to plg (0.703974 and 0.703739, respectively) and wr (0.703908 and 0.703711) and the wr composition is the least radiogenic in all the three samples. The higher (⁸⁷Sr/⁸⁶Sr)ᵢ values of the cpx are consistent with a late formation of them from a residual magma.

References


**SUMMARY LAST YEAR’S ACTIVITY**

**Courses:**


B. CESARE: “Fluids inclusions”, Dipartimento di Geoscienze, Università degli Studi di Padova.


S. BOESSO: “Introduzione alla biblioteca”, Dipartimento di Geoscienze, Università degli Studi di Padova.

S. BOESSO: “Gestire le bibliografie con Refworks”, Dipartimento di Geoscienze, Università degli Studi di Padova.


**Teaching activities:**


**Other:**

Field activity

India, January-February 2011

Lab activity

Processing of samples from India for the preparation of thin sections, XRF analyses and ICP-MS analyses, Dipartimento di Geoscienze, Università degli Studi di Padova.

Preparation of tablets for XRF analyses, Dipartimento di Scienze della Terra, Università degli studi di Napoli Federico II.

Hand picking of samples for Sr-Nd-Pb isotope analyses, Dipartimento di Geoscienze, Università degli Studi di Padova.