BASIC VOLCANISM ALONG K-T BOUNDARY FROM RAJAHMUNDRY, EAST COAST OF INDIA

A.T. RAO, K. SRINIVASA RAO and V. VIJAYAKUMAR
Department of Geology, Andhra University, Visakhapatnam - 530 003

Basalts near Kateru, north of Rajahmundry in the East Godavari district and near Pangidi in the West Godavari district of Andhra Pradesh along the East Coast of India are of particular interest to investigators on account of their separation from the well known West Coast Deccan Basalts, localised around Bombay. The basalts around Rajahmundry are tholeiitic with equigranular, subophitic to ophitic textures. The principal constituents are plagioclase (An_{55-66}) and brownish nonpleochroic augite. The REE patterns of Rajahmundry basalts have a marked increased enrichment in LREE due to crustal contamination. The K-Ar age of Kateru basalts is 75.1±4.9 Ma. The reported biochronostratigraphy of microfauna in the sediments closely associated in time and space with basalt flows in the Krishna-Godavari basin, east of Rajahmundry indicate that the age of basic volcanism is around 67 Ma. The lower limit of 70 Ma for the Kateru basalts supports that these basalts have evolved along with West Coast Deccan Basalts (69-65 Ma), where, the intensity of basic magmatism is more. The geological setting of Rajahmundry basalts with coastal sedimentary rocks indicate that the basic magmatism and sedimentation had taken place during the Cretaceous-Tertiary boundary.

The Gondwana group of sedimentary rocks, the outliers of basic volcanics and the Rajahmundry sandstone in the Kateru-Pangidi region of the both East and West Godavari districts of Andhra Pradesh have attracted the attention of geologists (Bhalla, 1967; Baksi, 1977; Raju et al. 1995; Katharin et al. 1998). Outcrops of basalts near Kateru, north of Rajahmundry in the East Godavari district and near Pangidi in the West Godavari district (Fig. 1) along the East Coast of India are of particular interest for earth scientists on account of their separation from the well known West Coast Deccan Basalts in the Mumbai region. The sedimentary formations around Rajahmundry include the Gollapalli sandstones (Middle Jurassic), Raghavapuram shales (Lower Cretaceous), Tirupati sandstones (Middle Cretaceous), Infra-trappean sandstones, fossiliferous Inter-trappean limestone (Palaeocene) and Rajahmundry sandstones (Mio-Pliocene). Amidst these sedimentary rocks, the basalts (referred to as traps in the literature) occur as outliers in both East and West Godavari districts.

Several basic volcanic flows equivalent to Deccan Basalts are also exposed in small patches in the Krishna-Godavari sedimentary basin away from the main bodies of basalts around Rajahmundry. Intertrappean sediments are characterised by planktic foraminifera and calcareous nanofossils. Based on their biochronostratigraphy, the age of basic volcanism is inferred to be around 67 Ma (Raju et al. 1995; Katharin et al. 1998).

The area under investigation is interesting in that in a small domain of about 700 sq. km, various rock units are exposed. Thus they form a unique setting for understanding stratigraphical problems such as the Cretaceous-Tertiary boundary and the age of basic volcanism. In view of the vast literature available on the Deccan Basalts, an attempt is made here to present the major and trace element geochemistry of basalts of the Godavari districts to appreciate their geochemical evolution and tectonic setting.

Petrography of Basalts

The maximum thickness of the lower basalt in the stratigraphic sequence rarely exceeds five metres. This is best exposed in the Pangidi-Gauripatnam area where at present active quarrying is being carried out. These basalts are fine grained and equigranular, with subophitic to ophitic textures, and characterised by spheriodal weathering. They appear massive and greenish black in colour, and occasionally exhibit porphyritic texture with a hyaloophitic textured groundmass. Principal constituents in the rock are plagioclase (An_{55-66}) and brownish non-pleochroic augite ($2V_\gamma = 45°-53°$ and $\gamma : Z = 45°$). Fe-Ti ores, pigeonite and glass are the accessory constituents.

The upper basalt in the stratigraphic sequence is best exposed in the Dudukuru-Gauripatnam tract on the right bank of the Godavari river course and in the Kateru quarries on its left bank. It is about 20 m thick, massive, dark-grey and often characterised by vesicles on the top and amygdules containing quartz, chert, calcite etc., as noticed in the quarry section of Kateru. In thin section, it is semicrystalline and porphyritic, with hyaloophitic textured groundmass.

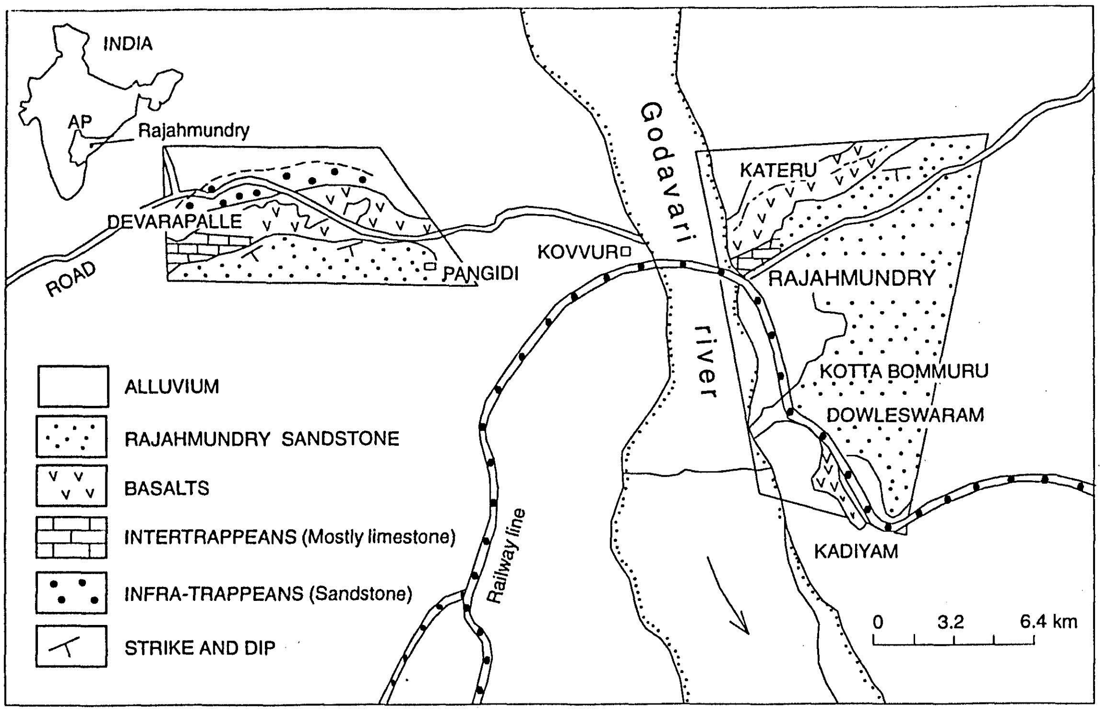

Fig.1. Geology of Kateru-Pangidi area around Rajahmundry (*after* Raju et al. 1965).

Plagioclase (An_{70}) phenocrysts of 3 x 0.8 mm in size are clustered into aggregates. Microphenocrysts of clinopyroxene also occur in aggregates. Accessory pigeonite is found in association with augite. Pigeonite has $2V_\gamma = 25°$; V_γ:Z = 40° and augite shows $2V_\gamma = 50°$ and V_γ:Z = 45°. Magnetite is present as microphenocrysts. Haematite and ilmenite occur as platelets in mesostasis. Green opal and chalcedony occur throughout the rock encrusting small vesicles. Mesostasis consists of devitrified glass containing plagioclse laths, pyroxene granules and platelets of haematite and ilmenite. The mineralogical composition of lower and upper basalts are remarkably similar.

Table 1. Major element (in wt.%) analysis* of the Rajahmundry basalts

Elements	Kateru n = 27	Pangidi n=27
SiO_2	49.33 ± 0.85	49.57 ± 0.87
TiO_2	2.25 ± 0.63	2.41 ± 0.67
Al_2O_3	13.11 ± 0.72	12.81 ± 0.70
Fe_2O_3	3.55 ± 0.61	3.69 ± 0.63
FeO	10.10 ± 0.61	9.97 ± 0.60
MnO	0.18 ± 0.01	0.18 ± 0.01
MgO	5.33 ± 0.53	5.00 ± 0.44
CaO	9.83 ± 0.65	9.74 ± 0.64
Na_2O	2.72 ± 0.35	2.93 ± 0.37
K_2O	0.65 ± 0.10	0.62 ± 0.09
P_2O_5	0.28 ± 0.05	0.29 ± 0.05
H_2O^+	2.78 ± 0.45	2.94 ± 0.47
Total	**100.11 ± 0.16**	**100.15 ± 0.15**

* Determined by WDXRFS method on pressed powder pellets, following the procedures given by Govil (1985). FeO - Volumetric method; H_2O^+ - wet chemical analysis.

Geochemistry of Rajahmundry Basalts

The major, trace element and REE geochemistry of the Rajahmundry basalts are given in Tables 1and 2.

The Kateru and Pangidi basalts around Rajahmundry (Fig. 2) are tholeiitic. The chondrite-normalised REE patterns (Fig.3) have a marked enrichment in light REE, comparable to continental flood basalts in general.

According to Philpotts (1994), continental flood basalts are not primitive, but derived from slightly depleted mantle source and have undergone some crustal contamination.

K-Ar Age and Tectonic Evolution of Rajahmundry Basalts

The K-Ar age of the Kateru basalts was determined by Kruger Enterprises, Inc., Geochron. Laboratories Division, 24, Black Stone Street, Cambridge, Massachusetts 02139 USA.

The age reported is 75.1±4.9 Ma for the Rajahmundry basalts. Terrestrial magmatism most commonly occurs in association with active plate boundaries, either convergent (subduction zones) or divergent (continental and oceanic rifts). Compositions of magmas from these different settings are not simple or straightforward, particularly in continental settings when the mantle source characteristics of mafic

Table 2. REE and Trace element data (in ppm) of the Rajahmundry basalts

Element	Kateru	Pangidi
REE		
La	16	17
Ce	36	40
Pr	5	6
Nd	23	25
Sm	6	7
Eu	2	2
Gd	5	5
Tb	1	1
Dy	5	5
Ho	1	1
Y	36	40
Er	4	3
Tm	0.41	0.56
Yb	4	4
Lu	0.64	0.58
Trace Elements		
Co	56	50
Ni	44	38
Cu	376	300
Zn	121	110
Ga	17	20
Pb	5	6
Bi	70	75
Rb	3	4
Cs	0.03	0.05
Ba	96	110
Sc	29	30
V	300	250
Ta	2	1
Cr	16	54
Hf	10	7
Th	2	2
Nb	12	15
U	0.30	0.50
Sr	227	210

Trace elements and REE concentration were determined by ICP-MS method (Balaram et al. 1992)

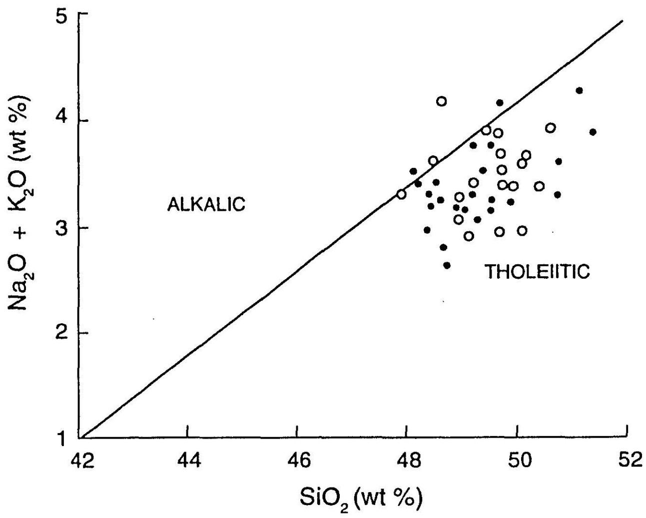

Fig.2. Total Alkalies vs Silica Plot (*after* Macdonald and Katsura, 1964) for the basalts around Rajahmundry. (O- Pangidi; • - Kateru)

magmas may be obscured by contamination with crustal material. The REE patterns of basalts around Rajahmundry suggest that they have undergone some crustal contamination. The outpouring of basalts is generally interpreted as marking the site of a mantle plume hotspot.

The lower limit, 70 Ma of Rajahmundry basalts indicates that they are coeval with the evolution of Deccan Basalts (69-65 Ma) in the West Coast (Hooper et al. 1988). The biochronostratigraphically inferred ages around 67 Ma age for the basic volcanism in Krishna-Godavari basin near Rajahmundry (Raju et al. 1995; Katharin et al. 1998) supports its possible relationship with the Reunion plume.

The upper limit of 80 Ma for the Rajahmundry basalts does not coincide with Madagascar-India rifting connected to Marion plume as the Madagascar basalts have the mean age of 88 Ma (Storey, 1995). The Rajmahal Traps of northeastern India and the 85°E ridge in the northeastern Indian Ocean are reported to be the trace of the Crozet hotspot (Curray and Munasinghe, 1991). But, Storey (1995) has indicated that Rajmahal basalts (115-117 Ma) are related to Kerguelen plume (Fig. 4A). Further, Storey (1995) has referred that the Marion plume around 88 Ma has promoted the formation of Madagascar basalts, while the

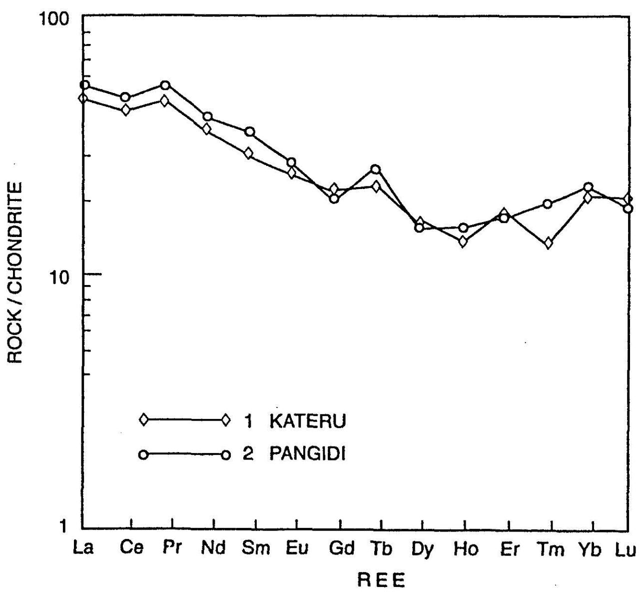

Fig.3. Chondrite-normalised REE plot of basalts around Rajahmundry.

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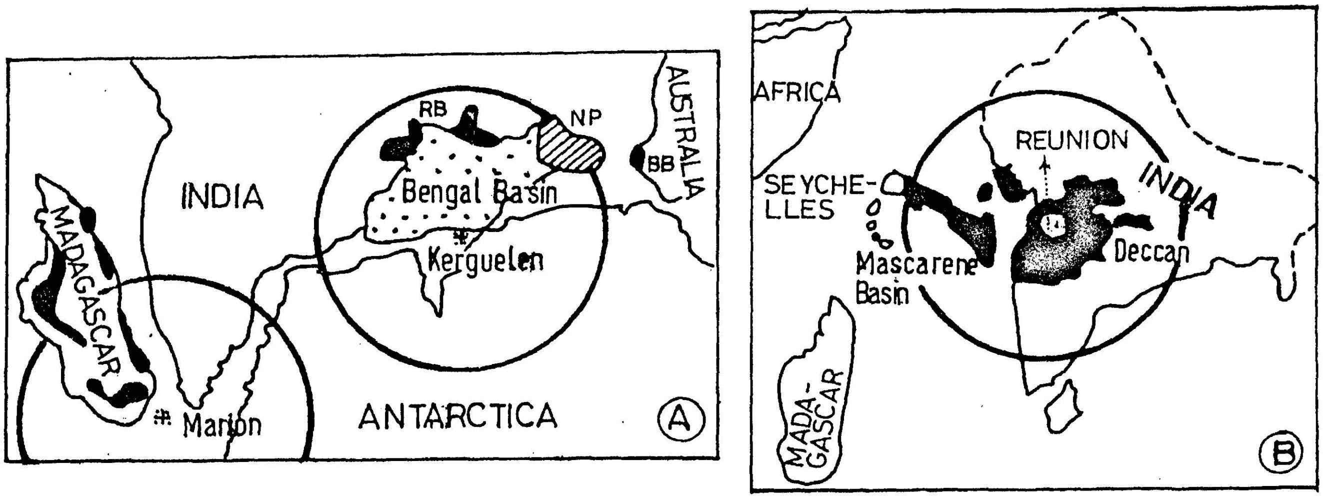

Fig.4. A schematic diagram illustrating the location of Rajmahal basalts (RB), Bunbury basalts (BB), Naturaliste Plateau(NP) and the possible extent of basalts within the Bengal basin (dots) together with the location of the Kerguelen plume (2,000 km in diameter). The illustration also shows the position of the Marion plume head (Fig. 4A; also 2,000 km in diameter) and basalt provinces. The known extent of the Deccan Basalt province and contemporaneous offshore basalts and the location of Reunion plume head (Fig 4B; 2,000 km in diameter) before separation of Seychelles from India (*after* Storey, 1995).

Reunion plume head, having 2000 km in diameter covering central India and west and east coasts, has influenced (Fig. 4B) the evolution of Deccan Basalt province (69-65 Ma) and contemporaneous offshore basalts. However, the geologic setting of Rajahmundry basalts, with coastal sediments and biostratigraphy, indicates that the basic magmatism and sedimentation have taken place along the Cretaceous-Tertiary boundary.

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References

Baksi, S.K. (1977) Marine transgression, sedimentation and tectonics of the west Godavari coastal rocks of Andhra Pradesh. Indian Jour. Earth Sci., S. Ray volume, pp.67-94.

Balaram, V., Manickyamba, C., Ramesh, S.L. and Anjaiah, K.V. (1992) Rare earth and trace element determination in iron-formation reference sample by ICP-MS. Atomic Spectroscopy, v.13, pp.19-25.

Bhalla, S.N. (1968) Cretaceous-Tertiary boundary in the Pangidi area, West Godavari district, Andhra Pradesh. Mem. Geol. Soc. India no.2, pp.226-233.

Curray, J. R. and Munasinghe, T. (1991) Origin of Rajmahal Traps and the 85°E ridge: Preliminary reconstructions of the trace of the Crozet hotspot. Geology, v.19, pp.1237-1240.

Govil, P.K. (1985) X-ray fluorescence analysis of major and selected trace elements in new IWG reference rock samples. Jour. Geol. Soc. India, v.26, pp.38-42.

Hooper, P.R., Subbarao, K.V. and Beane, J.E. (1988) The Giant Plagioclase Basalts (GPB) of the western ghats. In: Deccan Basalts. Mem. Geol. Soc. India, no.10, pp. 135-144.

Katharin, V. Salis and Saxena, R.K. (1998) Calcareous nanofossils across the K/T boundary and the age of the Deccan trap volcanism in southern India. Jour. Geol. Soc. India, v.51, pp.183-192.

Macdonald, G.A. and Katsura, T. (1964) Chemical composition of Hawaiian lavas. Jour. Petrol., v.5, pp.82-133.

Philpotts, A.R. (1994) Principles of igneous and metamorphic petrology. Prentice-Hall of India Pvt. Ltd., New Delhi, 498p.

Raju, D.S.N., Rao, C.N. and Sengupta, B.K. (1965) Paleocurrents in the Miocene Rajahmundry formation, Andhra Pradesh, India. Jour. Sed. Pet., v.35, pp.758-762.

Raju, D.S.N., Jaiprakash, B.C., Arun Kumar, Saxena, R.K. and Alok Dave (1995) Age of Deccan volcanism across KTB in K-G Basin: New evidence. Jour. Geol. Soc. India, v.45, pp.229-233.

Storey, B. C. (1995) The role of mantle plumes in continental breakup: case histories from Gondwanaland. Nature, v.377, pp.301-308.

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