CARBONATITE-SILICATE IMMISCIBLE MELT INCLUSION IN LAMPROPHYRE FROM KUTCH, WESTERN INDIA: IMPLICATION FOR PLUME-LITHOSPHERE INTERACTION AND INITIATION OF DECCAN TRAP MAGMATISM

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INTRODUCTION

The Kutch basin is an east-west oriented peri-cratonic rift basin in Western India (Biswas, 1987). The basin is located in the rifted northern part of Western Continental Margin of India (WCMI) (Fig. 1). WCMI is a typical volcanic passive margin that evolved during the separation of India-Madagascar and African plates during the period from Late Triassic to Late Cretaceous. The rifted basin developed during the early stages of the continental break up in Early Triassic – Late Jurassic time.

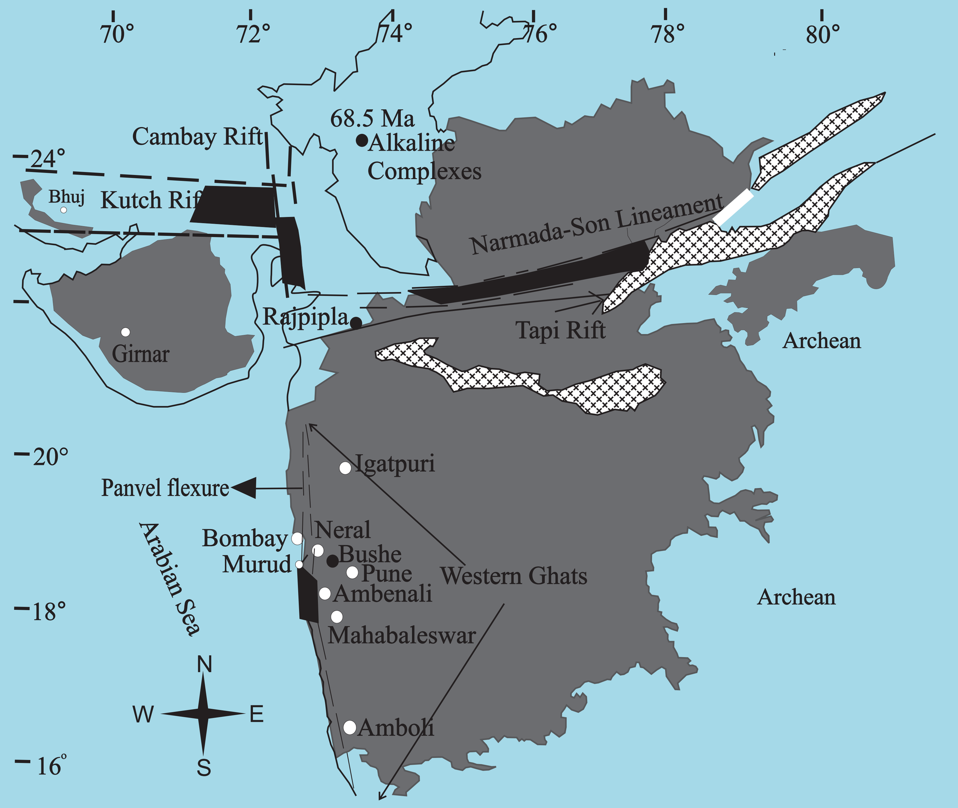


Fig. 1: Map of western India showing the location of the Deccan Volcanic Province (DVP), the Son-Narmada lineament, the Cambay and Kutch rifts. Distribution of alkaline igneous complexes in the DVP is also shown. Location of Bhuj, area of present study, is in the western corner. (NPF- Nagar Parkar Fault, NKF- North Kathiawar Fault)

GEOLOGY OF KUTCH

- Kutch province of western India has undergone repeated rifting and marine transgression events from late Triassic to the late Cretaceous. There are number of fault controlled uplifted blocks in the Kutch Basin-Kutch Mainland Uplift (KMU), Pachchham Uplift (PU), Khadir Uplift (KU), Bela Uplift (BU), Chorar Uplift (CU), Wagad Uplift (WU) (Fig.2).
- Magmatic rocks occur in profusion in Kutch Basin. The southern part of KMU is characterized by occurrences of thick flows of tholeiitic basalt of Deccan Trap affinity. The central part of KMU is dominated by occurrence of mantle xenolith bearing alkali basalt plugs and tholeiitic dykes and sills.

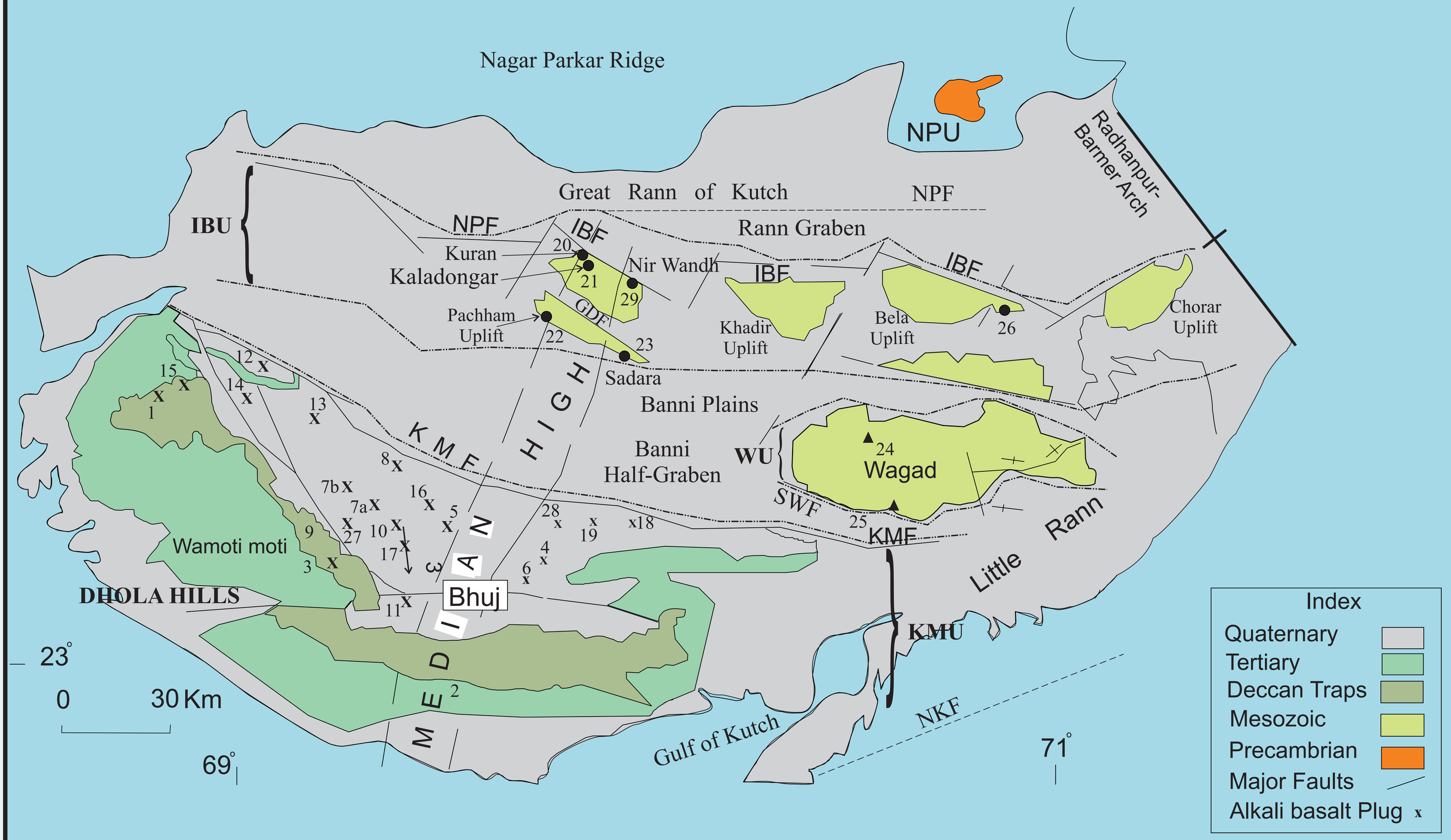


Fig. 2: Geological map of Kutch rift basin (modified after Biswas 1987)
Index to localities:

1. Pranpur, 2. Dhanoi, 3. Wamoti Moti, 4. Bhujia, 5. Bharar, 6. Kingriya Dongar, 7a. Vithon, 7b. Nakhatrana, 8. Dinodhar, 9. Ranadada,10. Jaksh, 11. Dhrubia, 12. Kaya Dongar, 13. Keera Dongar, 14. Lakhpa-Khatieu, 15. Likhi Hill, 16. Dhar Dongar, 17. Nana Dongar, 18. Jawharnagar-Kanyaber, 19. Lodai, 20. Kuran, 21. Kaladongar, 22. Raimalro, 23. Sadara, 24. Tromau, 25. Chitrod, 26. Sutana Dongar, 27. Sayra Dongar, 28. Habo Dome, 29. Nir Wandh Complex.

NPU - Nagar Parkar Uplift; NPF - Nagar Parkar Fault; IBF - Island Belt Fault; IBU - Island Belt Uplift;
KMF - Kutch Mainland Fault; KMU - Kutch Mainland Uplift; WU - Wagad Uplift; NKF - North Kathiawar Fault;
SWF - South Wagad Fault.

MAGMATIC ROCKS OF PACHCHHAM ISLAND

The Pachchham Island of northern Kutch is dominated by suite of alkaline magmatic rocks similar to magmatic rocks of continental rift zone(Fig. 3, 4). The alkaline suite contains alkali pyroxenite, theralite(Fig. 7), teschenite(Fig. 8), basanite, nepheline syenite and kaersutite bearing lamprophyre (Ray et al., 2006, 2010, Das et al., 2007, Paul et al., 2008). The newly discovered east-west trending lamprophyre dyke swarm (Fig. 3,4,5,6) of northern Kutch (Core of Kaladongar anticline and rocks of Nir Wandh Complex of Pachchham Island) is camptonite in composition and contains kaersutite phenocrysts

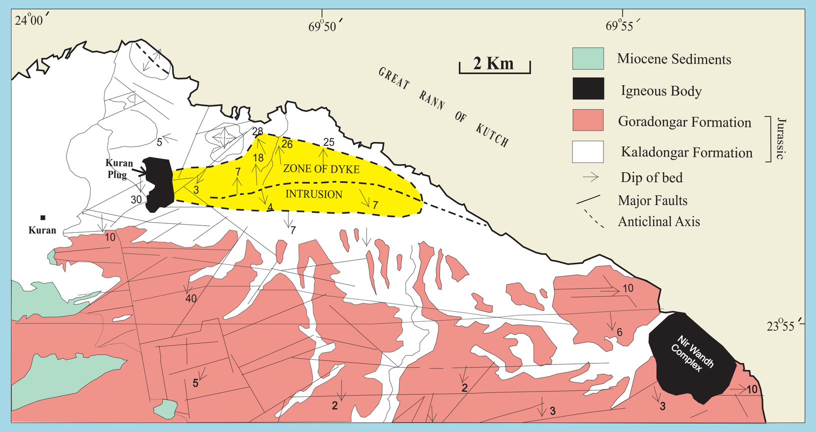


Fig. 3: Detailed geological of the Kaladongar Hill, Kutch. The location of Kuran plug, Nir Wandh Complex and zone of dyke swarms also shown (modified after Das et al. 2007).

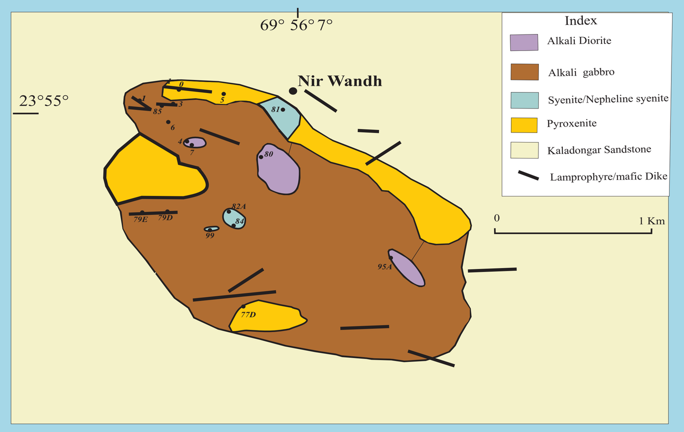


Fig. 4: Geological map of Nir Wandh Igneous Complex, Northern Island Belt, Kutch (modified after Paul et al. 2008).

Fig. 5: Core of Kaladongar Anticline with Lamprophyre Dyke swarms

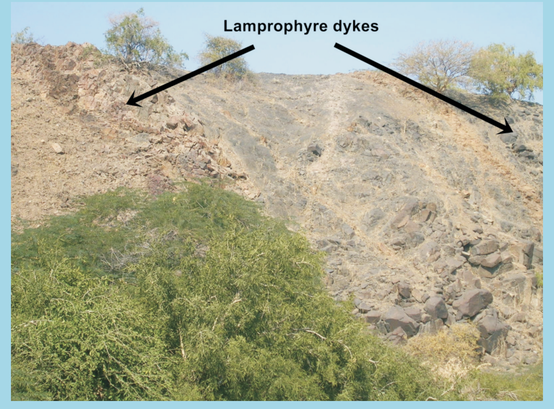


Fig. 6: Lamprophyre dykes of Nir Wandh area, intruding Kaladongar sandstone, Pachchham Island

PETROGRAPHY OF LAMPROPHYRE

The lamprophyre of Nir Wandh is characterized by phenocryst of kaersutite, clinopyroxene, alkali feldspar and rarely olivine. The composition of pyroxene ranges from $Wo_{49}Fs_{25}En_{26}$ in the core to $Wo_{48}Fs_{9.5}En_{42.5}$ in the rim. Few olivine grains found in lamprophyre dyke are forsteritic (Fo77). Kaersutite grains are high Mg (10-11%) high Ti (5.5-5.6%) and their total alkalis are ~5%. They contain euhedral sphene. Tabular shaped alkali feldspar varies in composition from $Or_{68}Ab_{31.3}An_{0.7}$ to $Or_{31.6}Ab_{66.6}An_{1.8}$ The groundmass consists of plagioclase, kaersutite, clinopyroxene and opaque. The groundmass kaersutite grains are Fe rich (24-30%) with low Ti and low Mg (Fig.10).

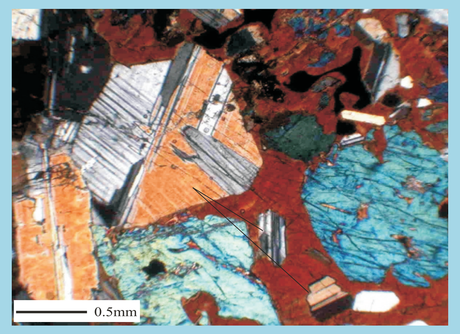


Fig. 7: Clino-pyroxene, olivine and plagioclase enclosed within kaersutite in alkali gabbro of Nir Wandh Complex, Pachchham Island.

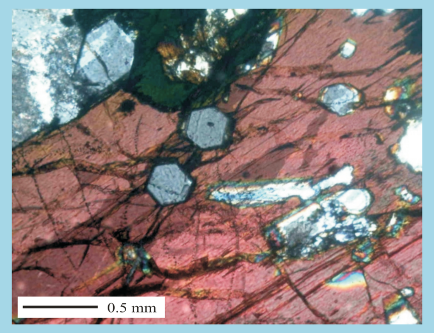


Fig. 8: Euhedral apatite as inclusion within kaersutite in alkali diorite of Nir Wandh Complex, Pachchham Island.

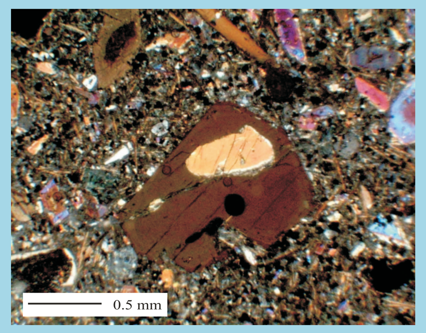


Fig. 9: Subrounded inclusion of opaque and olivine in kaersutite phenocryst in lamprophyre of Pachchham Island, Nir Wandh Complex.

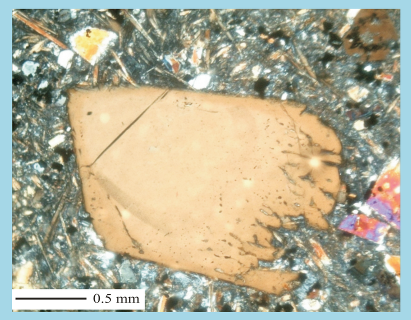


Fig. 10: Pleochroic haloes and corroded margin in kaersutite of fine grain lamprophyre dykes of Kaladongar anticline, Pachchham Island.

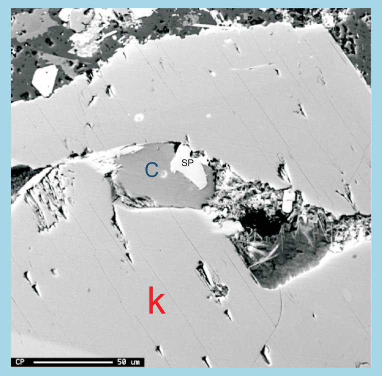


Fig. 11: Carbonatite melt inclusion in kaersutite, sphene in carbonatite, C-carbonatite, sp-sphene, K-kaersutite.

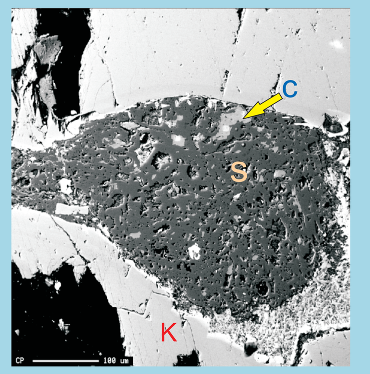


Fig. 12: Carbonatite melt inclusion within silicate melt in kaersutite. C-carbonatite, S-silicate, K-kaersutite.

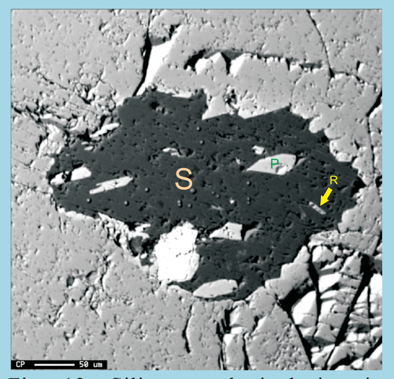


Fig. 13: Silicate melt inclusion in kaersutite, with pyroxene, rhonite crystal. S-silicate, P-pyroxene, R-rhonite.

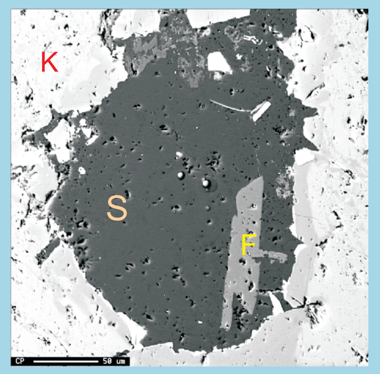


Fig. 14: Silicate melt inclusion within alkali feldspar in kaersutite. S-silicate, F-feldspar, K-kaersutite.

MELT INCLUSION IN KAERSUTITE PHENOCRYST OF LAMPROPHYRE

The melt patches in kaersutite phenocrysts of are of two types-- calciocarbonatite and alkaline silicate melts.Silicate melt inclusion in lamprophyre are commonly irregular, elliptical with long dimension 330um and short dimension 180um and are characterised by the presence of euhedral amphibole, clinopyroxene and rhonite(Fig. 13). Carbonate melt inclusions are circular, irregular often squarish and have dimension 60um/45um. Within carbonate melt phase euhedral sphene occurs(Fig. 11, Table 1). Calcio-carbonatite melt also occurs as lenticular, elliptical and irregular immiscible in silicate melt patch(Fig. 12). Melt patches in kaersutite phenocrysts are vesicular indicating presence of volatile phases (Fig.14).

Table 1: Composition of carbonatite and silicate melt inclusion in kaersutite phenocrysts of lamprophyre of Pachchham Island, Kutch Basin

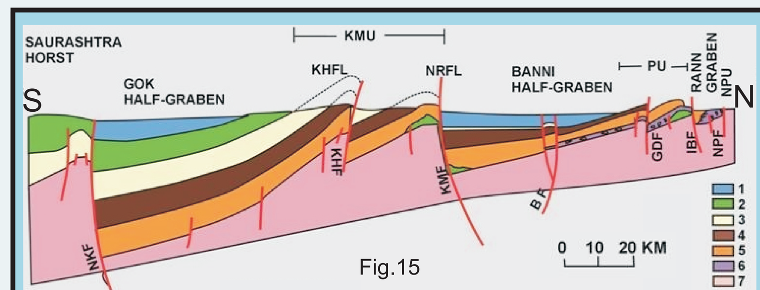
Carbonate Melt Inlcusions											
SiO_2	TiO_2	Al_2O_3	Feo*	MgO	CaO	Na_2O	K_2O	MnO	Cr_2O_3	NiO	Total
2.08	0.34	0.91	1.14	3.04	54.36	0.1	0.013				61.98
0.08	0.01	0.01	0.15	0.03	54.3	0.1	0.01				54.69
Sphene crystal in the Carbonatite melt inclusion in Lamprophyre											
31.27	32.63	3.77	1.31	0.06	27.64	0.04					96.72
Silicate Melt Inclusions											
38.95	3.85	13.09	16.64	9.37	11.49	3.9	1.02				98.31
46.764	2.95	7.61	7.113	12.547	22.399	0.641	0.01				100.2
Rhonite in Silicate melt											
27.66	8.934	16.52	22.41	10.51	11.27	1.199	0.039	0.213	0.05		98.82

DISCUSSION

In the Mesozoic Kutch Basin the tectonic episodes were accompanied by deep crustal magmatic activity (Biswas, 2005, Ray et al., 2006, Paul et al., 2008, Sen et al, 2009). Kutch experienced lithospheric thinning due to rifting leading to rupture of the crust-mantle boundary (Fig.15,16,17) and subsequent intrusion in the upper crust during structural inversion (Biswas, 2005, Mandal, 2006, Mandal and Pandey, 2010). This synrift event was followed by Reunion hotspot related tholeiitic and alkalic volcanism during the Deccan Trap-K/T boundary event.

The Sr, Nd isotopic abundances of kaersutite lamprophyre indicates its derivation largely from this plume source with little contribution from rifted lithosphere (Fig. 18). The lamprophyre yields an age of ca. 67 Ma. by Ar-Ar method (Sen et al., 2014 in press). Petrographic evidence indicates that carbonatite melt occurs within alkali silicate melt as immiscible fraction. Strikingly these carbonatite melts are extremely rich in $CaCO_3$ (upto 95%) which contradicts the experimental results of carbonate melt composition (upto 80% CaCO3) in silicate-carbonate immiscible melt pair.

It has been proposed that carbonatite melt was generated below the lithosphere by low degree melting of the Deccan plume. In this model (Fig. 19), this low-degree, volatile-rich melts detached as tiny blobs from the cooler edge of the Deccan plume head and permeated the Kutch lithosphere as it was extending and fracturing due to plate-driving forces and caused carbonatite metasomatism of upper mantle. Partial melting of this carbonated peridotite yields $CaCO_3$ rich alkaline silicate melt. The carbonatite-silicate immiscible melt pair and its host lamprophyre possibly originated during the interaction of Reunion Plume with the rifted lithosphere beneath Kutch and mark the initiation of Deccan Trap magmatic activity.



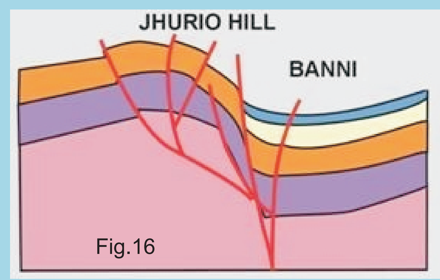
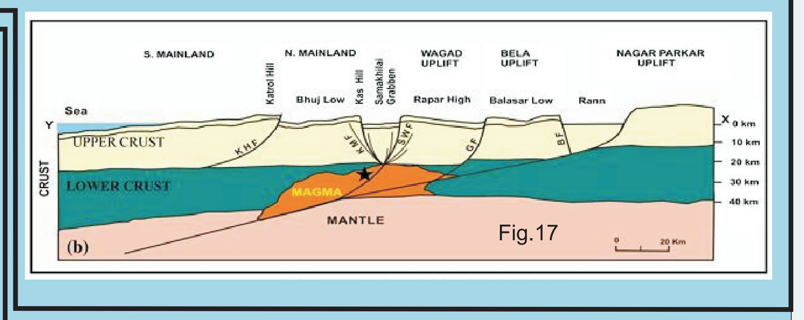


Fig. 15,16,17: North-south cross section of Kutch rift basin showing disposition of faults and faulted uplift (Fig.15), Fault net work (Fig.16) and deep faults penetrating crustal layer and reaching upper mantle-lower crust magma chamber (Fig.17)



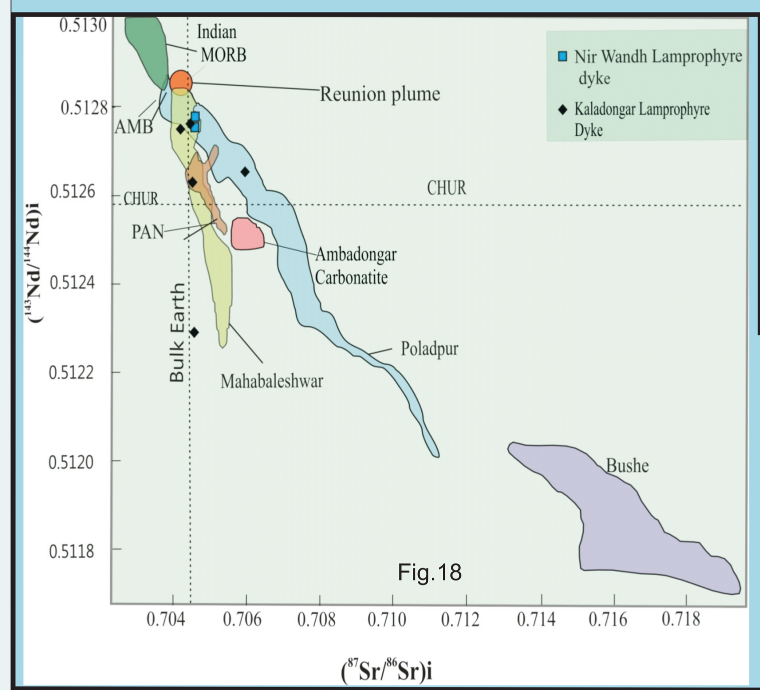
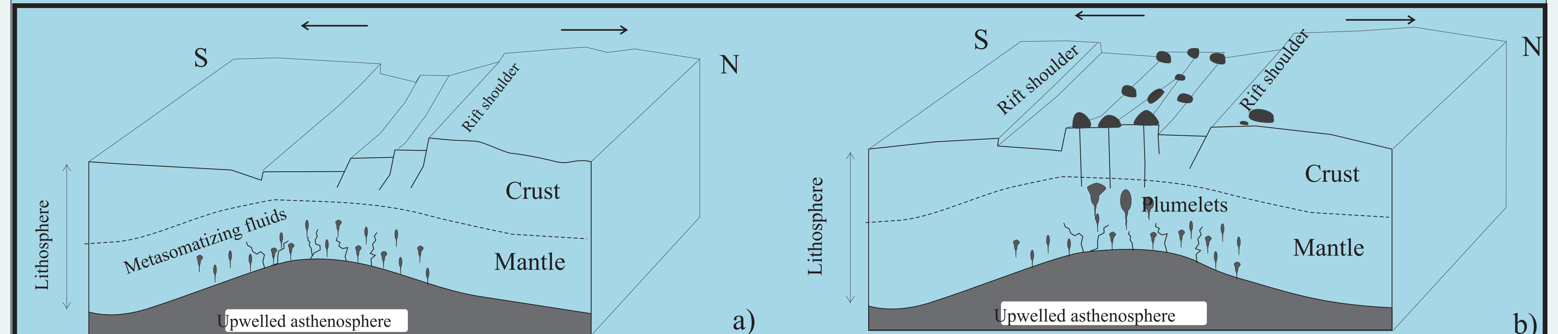


Fig. 18: Sr-Nd isotopic diagram showing fields of Reunion Plume, Indian Ocean MORB mantle, mantle compositions of Deccan Traps of Mahabaleswar Fmn, Bushe Fmn etc. Plots of kaersutite lamprophyres of northern Kutch are very close to field of Reunion Plume.(Data of Kaladongar lamprophyre after Das et al., 2007)



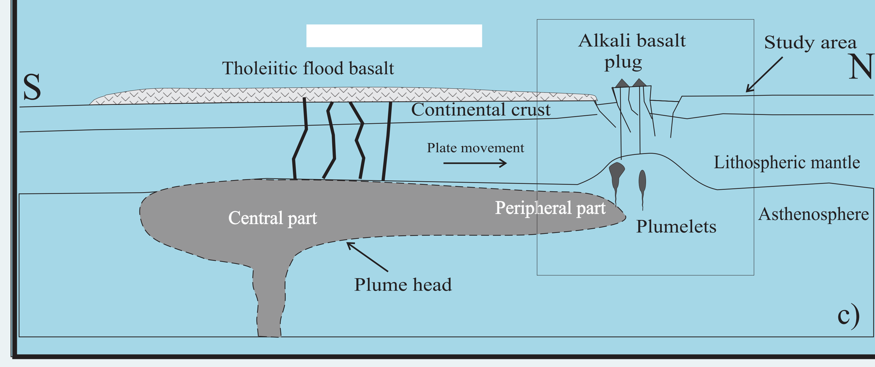


Fig. 19: HYPOTHETICAL MODEL (modified after Sen et al., 2009) showing stages of magma generation in Kutch Rift Basin- a): Mantle upwelling of lithosphere and decompression melting cause generation of low volume melt (fluid), which cause metasomatism of mantle source, b): Plume induced low degree partial melting of metasomatised mantle to produce alkali basalt. c): Disposition of Reunion Plume with its peripheral part lying below the Kutch Basin (Study area) and contributing material and heat (as plumelets) to produce alkali basalt and the central part of the Reunion Plume situated much southward produces tholeiitic basalt.

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