

OCCURRENCE OF RHYOLYTIC TUFFS AT DEEP SEA DRILLING PROJECT SITE 219 ON THE LACCADIVE RIDGE

H. N. SIDDIQUIE

National Institute of Oceanography

AND

R. N. SUKHESWALA

Geology Department, St. Xavier's College, Bombay.

Abstract

A study of thin sections from the lower and middle parts of Unit V (Paleocene) from Site 219 shows that these largely consist of acidic or rhyolitic tuffs. The overlying limestones in Unit V (Paleocene) and Unit IV (Lower Eocene) also contain tuffaceous material in varying proportions. Albite/oligoclase forms the phenocrysts as also needles in the groundmass of these tuffs and tuffaceous material in limestones. The euhedral fresh feldspars suggest that the source of activity was nearby and possibly most of the activity was subaqueous rather than subaerial. Similar acidic tuffs in the Deccan Traps have been reported particularly from the West Coast of India. The acidic tuffs at site 219 are of the same age as the Deccan Traps and may represent a late phase of Deccan Trap activity on the Laccadive Ridge before its subsidence and separation from peninsular India.

INTRODUCTION

The Indian Craton has long been regarded to have extended west, but has been partially faulted down in the Arabian Sea. Krishnan (1968) considered the Laccadive Trend to be continuing into the Cambay basin and further to the Aravalli range. He suggested that faulting during the mid-Miocene or later has brought down parts of Deccan traps beneath the sea. Pepper and Everhart (1963) visualised the Deccan Traps as extending further west upto even the Carlsberg Ridge. On the basis of offshore seismic surveys and interpretation of the tectonics of peninsular India, Eremenko (1966) and Eremenko and Datta (1968) concluded that the Laccadive formed the Western limit of the Indian Platform and the transition between the continental and oceanic crust passes to the west of the islands. Detailed geophysical surveys on the ridge have not been carried out and little is known about its structure and composition. Francis and Shor's (1966) seismic refraction studies in the North Western Indian Ocean included a profile on the Laccadive ridge in the Nine Degree channel. They reported that the 'profile reveals almost 5 km of volcanic rock (velocities 3.85 and 5.00 km/sec) overlying more than 10 km of crustal material and the Mohorovicic discontinuity at just over 17 km'. Bezrukov *et al*, (1966) described the basalts dredged by RV *Vityaz* from the Western flanks of the Laccadive ridge (RV *Vityaz* Station 4868-Fig. 1). The dredged material included samples of porphyritic basalt, with phenocrysts of plagioclase, pyroxene (augite) and opaques and glassy basalts. Hari Narain *et al*, (1968) proposed that Laccadive ridge continues NW-ward, through Bombay High upto Kori High, west of Karachi below the continental shelf. In 1972 during Leg 23 of her cruises DV *Glomar Challenger* drilled Site 219 (90°01.75'N 72°52.67'E) on the Laccadive ridge (Fig. 1) in the Nine Degree channel and a penetration of 411 m was achieved below the sea floor (1764 m below sea level). One of the authors (HNS) participated in Leg 23 and collected samples for subsequent

detailed laboratory studies. The hole penetrated a sequence ranging from Paleocene to recent. The shipboard party divided the sequence into five stratigraphic units (Table I, Fig. 2). Unit V was described as consisting of green yellowish-green and greenish-black limestone, sandstone, and siltstones (Whitmarsh, Weser and Ross, 1974). Subsequent studies at the Geology Division of the National Institute of Oceanography and the Geology Department of the St. Xavier's College, Bombay led to the conclusion that the lower part of Unit V largely contains acid felspathic or rhyolitic tuffs and even the overlying limestones of unit V and Unit IV contain significant amounts of volcanic material. The present note reports the results of these studies.

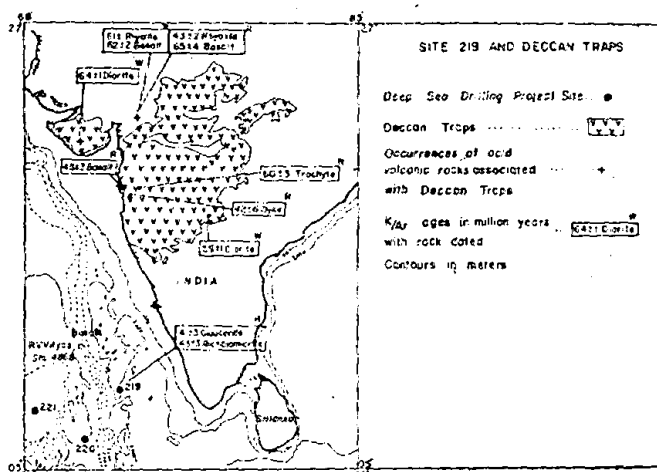


Figure 1. Map showing the location of Site 219 and Deccan Traps. Map partly based on initial reports of the Deep Sea Drilling Project Vol. 23. Additional data from references cited in text, K/Ar ages from Rama (1964) are marked R, Wellman and McElhinny (1970) are marked W and Hunziker and Matter (1974) as H. The locations of the large number of samples recently dated by Agarwal (1975) are not yet available.

DESCRIPTION

Traces of volcanic glass occur in the sediments of Unit II (Miocene) and Unit I (Pleistocene) but these are sparsely distributed in the dominantly biogenic sediments. Volcanic material becomes significant in the lower part of Unit IV. Thin sections of the Foram Chalk in Unit IV (219-25-CC) show fragments of tuff and large sized feldspar grains (albite/oligoclase) (Fig. 3a & b). The tuff fragments are mostly angular though in some cases rounding of edges is noticeable. The feldspar in some of these are aligned in such a way that these give the appearance of flow structure. The glass in some of the fragments is pitch dark and black whereas in others it is greenish and clear.

The underlying formations of unit V down to 219-A-6-1 are largely calcareous (63-68 per cent CaCO_3) but thin sections from these limestones show fragments of tuff, volcanic glass and unusually fresh feldspar dispersed throughout the rock (Fig. 3c).

The texture and composition of the rocks change significantly below barrel 6 core 1 (219A). Some of the rocks described earlier as sandstone, siltstone or claystone show a distinct igneous texture. The rock is fine grained with needles of

TABLE I

LITHOLOGIC SUMMARY, SITE 219

Unit	Subunit	Depth (m)	Thickness (m)	Corcs
I. Light-grey to greenish grey detrital silty clay, nanno ooze. The upper and lower portions are foram rich.		0-120	120	1-13(1)
II. White foram ooze and chalk, nanno rich in the upper part.		120-146	Ca26	13(1)-14
	IIIa. White foram nanno ooze and chalk.	146-165	23	15
III. White oozes and chalks containing nanos, forams, micarb and rads in varying proportion.	IIIb. White foram rich nanno micarb ooze and chalk.	165-178	13	16-17(1)
	IIIc. White rad rich micarb nanno ooze and chalk.	178-204	26	17(2)-20(2)
	IIId. White nanno rich rad micarb ooze, chalk and chert bands.	204-219	15	20(3)-21
IV. Greyish yellow to yellow brown micarb chalk and ooze, limestone, chert and clay.		219-300	81	219-22-28 219 A-1-2
	Va. Greyish green limestone, glauconite or tuff bearing or rich.	300-327	27	219 A-3-6(1)
V. Greyish green, dark grey and greenish black limestones and rhyolitic tufts.	Vb. Yellowish green to greyish green and dark grey limestone-glauconite or tuff rich and rhyolitic tufts—calcareous or glauconite rich.	327-365	38	219 A-6(2)-10(2)
	Vc. Dark greenish grey, dark grey and greenish black rhyolitic tufts.	365-411	46	219 A-10(3)-14

The sediment description in the lithologic summary follows the classification adopted by the Deep Sea Drilling Project (Whitmarsh *et al.*, 1974).

felspar (albite/oligoclase) and phenocrysts of similar composition. The glass is perlitic and the rock may be termed as rhyolite tuff (Fig. 3d). In the underlying barrel 8 (Sections 2-35-40 and 3-56-57) limestone reappears but tuffaceous material

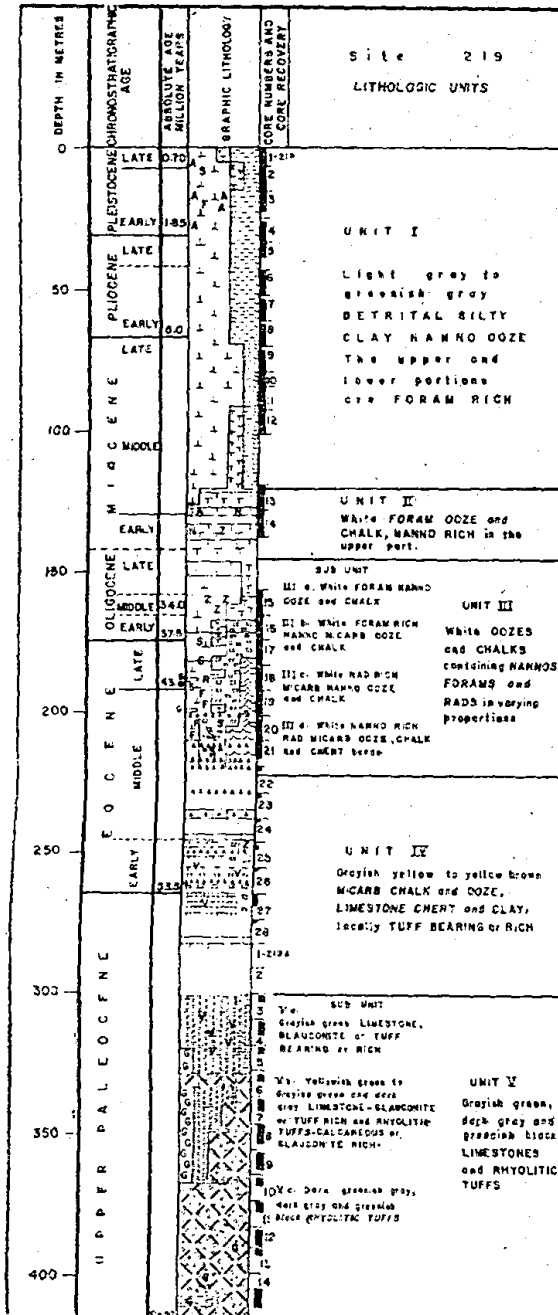


Figure 2. Lithologic summary, Site 219.

consisting of fragments of tuff and felspar laths is common in the limestone and the proportion of felspar is fairly high. Sections from the underlying barrel 10 (2-127-128 and 3-130-131) indicate shelly limestone with large felspar laths and needles. Below this limestone sequence tuffs again occur (11-2-82-83). Though calcitic veins cut

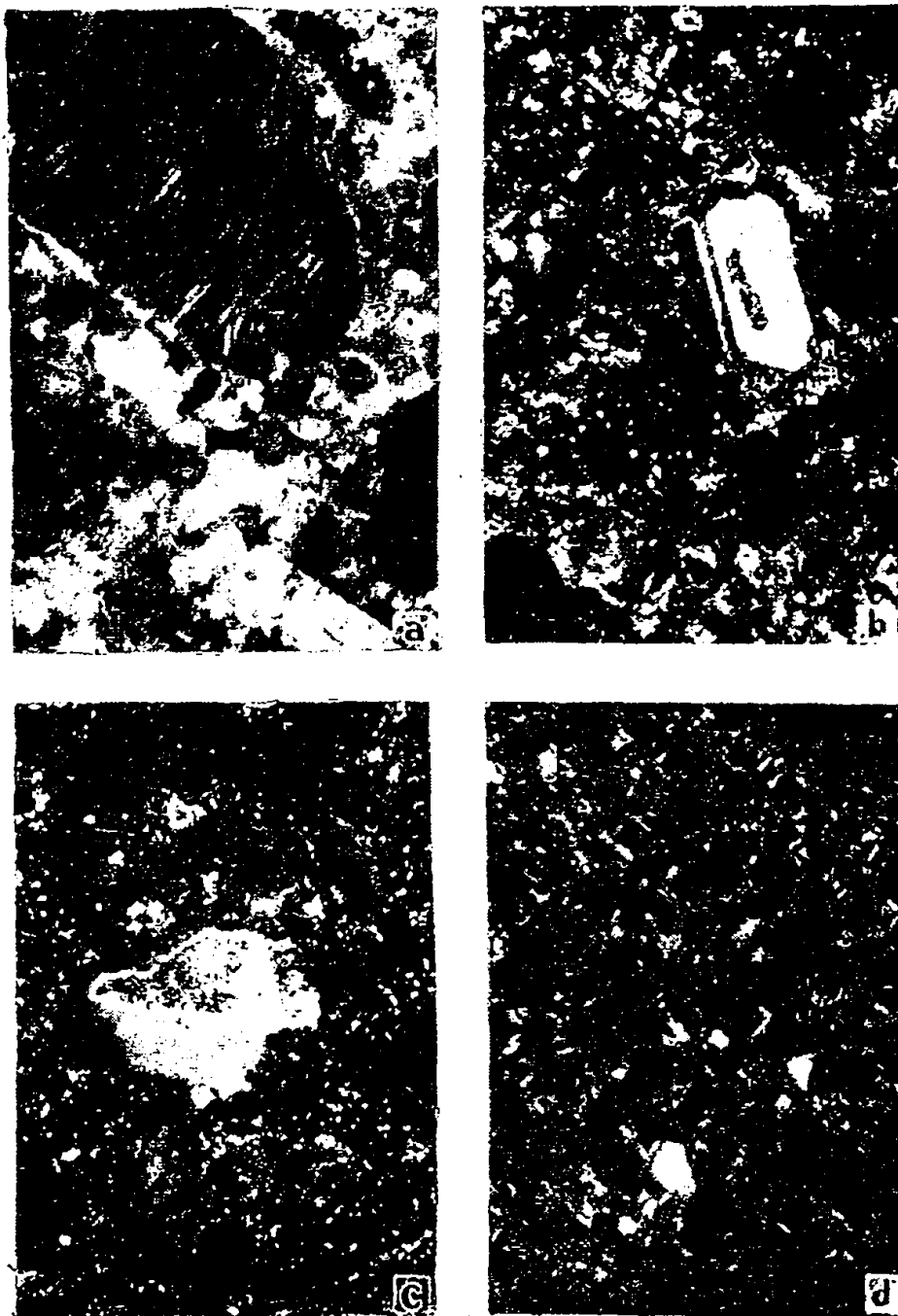


Figure 3a. Fragment of tuff and felspar (lower right) in Micarb Foram Chalk (219/25 CC, over polariser $\times 40$).

3b. Felspar in Micarb Foram Chalk (219/25 CC, Crossed nicols, $\times 40$).

3c. Felspar in limestone (219A/3/2/27-28, Crossed nicols, $\times 40$).

3d. Rhyolite tuff with felspar needles (white) (219A/6/2/34-35, Crossed nicols, $\times 55$).

across the rock, it is a rhyolite or acid felspathic tuff with tiny feldspar needles dispersed in glass. Rocks from the underlying barrels are similar rhyolitic or acid tuffs. A similar rhyolite or acid tuff is seen in the underlying barrel 14 but in the lower part an admixture of shells occurs.

Re-examination shows that Unit V may be divided into three sub-units. The revised lithologic summary for site 219 is given in Table I and shown in Fig. 2. A detailed study of the cores involving re-examination of the area and more closely spaced sections may necessitate a revision.

DISCUSSION

The available data seem to indicate that in Unit V volcanic activity continued intermittently with sedimentation. Sub-unit Vc represents a predominantly volcanic or igneous cycle consisting of acid felspathic or rhyolitic tuffs. The igneous cycle consists of acid volcanic rocks mainly containing feldspar or feldspar with glass. The feldspar is mainly plagioclase—albite and oligoclase and occurs as fine needles. The rock as a whole may be termed either acid felspathic tuff or rhyolite. Large crystals of albite/oligoclase are present either as phenocrysts in the acid rock or as clasts in the sedimentary rock. It appears that the igneous cycle was of subaqueous and not of subaerial origin. Even if it was of subaerial origin the eruption was very close to the ridge. Sub-Unit Vb represents an admixture of biogenous sediments and pyroclastics and a more detailed re-examination may even reveal alternate tuff and limestone beds. The overlying sub-Unit Va represents a predominantly biogenous limestone with tuff fragments. During the deposition of sub-Unit Vb the volcanic activity was intermittent at this site when sedimentation continued for a brief period and a limited amount of fauna also thrived. While sedimentation was continuing at this site volcanic activity occurred in nearby areas. The earlier tuffs were eroded and supplied. This is evidenced by the occurrence of tuffaceous material in the dominantly biogenous sediments.

The overlying limestone of sub-Units Vb, Va and lower part of Unit IV contain varying amounts of volcanic material. Large crystals of albite/oligoclase are present as clasts in sediments and appear quite fresh. Even individual feldspar crystals admixed with sediments are quite fresh and retain their original lath shape. Such crystals show no evidence of rounding and transport. However, the tuff fragments with parallel-oriented feldspar needles occurring in the sediments show rounded character. The composition of the fragments is the same as the rhyolitic tuff of the underlying formation. These coupled with broken feldspar crystals observed in sediments suggest that these were formed during a violent eruptive phase of volcanic activity.

With the culmination of volcanic activity in sub-Unit Vc, limited quantities of tuffaceous material were supplied to the overlying formation. These were either due to erosion of earlier tuffs or might have been supplied by volcanic eruptions in nearby areas. The tuffaceous material is found in the overlying limestone upto 25 CC. i.e., Lower Eocene. This may mark the last phases of volcanic activity on the Laccadive ridge and nearby areas.

The dominant volcanic nature of sub-Unit Vc and significant volcanic contribution to sub-Units Va and Vb and the overlying lower part of Unit IV is also supported by mineralogical and geochemical studies. The rocks in these units contain a high proportion of montmorillonite (49 per cent in a bulk sample and 59.1–92.2 per cent

in a 2 micron fraction) with a high percentage of plagioclase (2.0 to 43.6 per cent in various fractions) and in some cases clinoptilolite (1.1 to 42.7 per cent in various fractions) (See Matti *et al*, in Whitmarsh *et al*, 1974). The heavy mineral assemblage indicates a high concentration of anatase in these rocks and sediments. Geochemical studies (P.S.N. Murthy, Personal Communication) also indicate a high percentage of iron (2.19–8.08 per cent), manganese (402–1823 ppm) and titanium (0.49–1.43 per cent). These concentrations are many times more than in the overlying biogenous formations. All these data tend to support the dominant volcanic origin of the sequence in Unit V. Francis and Shor's (1966) contention that the upper refractive horizon with a measured velocity of 3.85 km/sec is a volcanic rock may therefore be correct.

The occurrence of volcanic activity at the Laccadive ridge in the Paleocene and Lower Eocene is of considerable interest. Besides the Deccan Traps in India, basalts of similar age have also been recorded from the Indian Ocean floor. Bezrukov *et al* (1966) gave K/Ar age of 51 to 63 million years for samples of basalt from the southern Indian Ocean. Hunziker and Matter (1974) dated two samples of 'glauconite rich biomicrite' from Unit V by K/Ar method and obtained ages of 41.6 and 43.9 million years. Apparently these estimates are on the low side due to the loss of argon or absorption of potassium or both. The K/Ar ages are not conclusive and therefore the ages already arrived at on paleontological evidence may be accepted. The igneous activity encountered at site 219 extends from Paleocene to lower Eocene. The Deccan Trap activity on peninsular India is of the same age and ranges from Cretaceous to Eocene (Krishnan, 1968). K/Ar dates of the Deccan Traps by Rama (1964) which were revised subsequently by Wellman and McElhinny (1970) indicate a 59 to 64 million years age (Early Paleocene) (Fig. 1). Recent K/Ar dating of fifty samples of Deccan Traps, Rajmahal Traps and Gondwana dykes by Agarwal (1975) indicates that the outpouring of Traps commenced in Early Paleocene (~65 my) and the traps in the western and southern regions were laid quickly (i.e. within 5-7 my) but the traps in the north eastern region have been dated to be mid-Eocene (~47 my) and while the dykes in the traps have been dated from 63-64 my. Agarwal (1975) therefore gives the time span of Deccan Trap activity to be from Early Paleocene to beyond Eocene (65-34 my). The Deccan Traps are basaltic in composition, but acid varieties are known particularly from the western margin (St. Mary's Island, Bombay, Rajpipla, Girnar and Pavagarh etc., Fig. 1). The acid varieties are generally regarded as younger and are thin compared to the large thickness of the underlying basalts (maximum thickness 2000 m at Bombay). The rhyolitic tuffs at site 219 may therefore, represent a late manifestation of acidic activity in the traps. Seismic refraction data of Francis and Shor (1966) indicates a 5 km thickness of volcanic material on the ridge. Based on a comparison with the basalt rhyolite association on land, it is reasonable to infer that at Site 219 the rhyolitic tuffs penetrated (sub-unit Vc ≈ 46 m) are a thin capping over a large thickness of basalts. It is therefore possible that the igneous activity on the Laccadives is just a westward extension of the Deccan Traps on the Indian Sub-continent.

CONCLUSIONS

The Paleocene formation (Unit V) consists of limestone and rhyolitic tuffs. The lower 46 m consist of rhyolitic tuffs, overlain by limestones and rhyolitic tuffs (38 m), followed by limestones (27 m) which contain fragments of tuffaceous material.

The rhyolitic tuffs (Upper Paleocene) mark the end of volcanic activity on the site and are possibly underlain by a much larger thickness of basalts. Probably the explosive activity in nearby areas continued till Lower Eocene. The acid felspathic tuffs are of the same age as those occurring in the Deccan Traps at many localities on the West Coast of India, and may represent a manifestation of the Deccan Trap activity on the Laccadive ridge.

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