

# Morphology of an Uncharted Seamount from Central Indian Basin

V. N. KODAGALI

National Institute of Oceanography  
Dona Paula-Goa, India 403 004

**Abstract** *The morphology of a seamount at 12°35' S and 76°16' E is studied. This conical seamount has a maximum height of 1275 m (water depth 4135 m) and covers an area of about 189 sq km. The maximum basal extension is about 24 km. The mount is gentler and lengthier on the western flank and steeper and shorter on the eastern flank. A conspicuous flat steplike feature is present on the western flank. Slope angles are high (up to 35°). The trend of the seamount is approximately NNE-SSW. Dredging yielded basalts containing ferromanganese encrustations indicating its volcanic origin.*

**Keywords** Morphology, seamount, contour map, profiles, slope angles, volcanic origin

## Introduction

Because of their importance as physiographic features beneath the sea, seamounts have evoked considerable interest among geomorphologists. There are numerous seamounts reported and studied from the world oceans, especially from the Pacific and Atlantic. The Hawaiian-Emperor chain in the Pacific is reported to contain more than 1000 mountains of varying size (Pratt 1963; Davies, Wide, and Clague 1972; Larina 1975; Irish 1976; Walgate 1984). There are reportedly more than 12,000 big and small mounts in the Pacific Ocean alone (Batiza 1982). The presence of a seamount can be detected if good quality bathymetric data are available. Probably because of the lack of such data from the Indian Ocean, very few seamounts have been reported. A general survey of International Hydrographic charts of this area also supports the presence of few such mounts.

Seamounts have profound influence on mixing processes in the deep oceans. A seamount can influence up to three times its height above the neighboring abyssal plains and to a horizontal distance equal to three times its width (Gould, Hendry, and Huppert, 1981). They are also a sort of marker of plate movements. In the Pacific Ocean (Handschumacher 1973), the Emperor chain might have formed along the boundary between the stable portion of ocean crust and the active spreading ridge migrating parallel to the boundary. Furthermore, the study of seamounts is important in areas where polymetallic nodules occur. Seamounts are the suppliers of nodule nuclei (Horn, Horn, and Delach 1973). A considerable area around these features will have a very high abundance of nodules, albeit a lesser concentration of elements (Kodagali 1988). However, seamounts can pose hazards to future mining operations. Hence it is necessary that such features be studied in detail and their extent marked to avoid obstacles to mining.

### Area and General Bathymetry

The Central Indian Basin has an area of  $5.6 \times 10^6$  sq km limited by a mid-Indian ridge in the west and  $90^\circ\text{E}$  ridge on the east. The northwest extension of the basin is the Chagos plateau. Manganese nodules deposits of economic importance are reported from this basin (Frazer and Wilson 1980). The National Institute of Oceanography in Goa, India, during surveys for polymetallic nodules in the Central Indian Basin, has collected great amounts of echo-sounding data. An uncharted seamount encountered during one of the cruises of the ORV *Sagar Kanya* was studied, and the results are presented here.

The seamount has a height of about 1275 m with its peak at a water depth of 4135 m, at  $12^\circ35'\text{S}$  and  $76^\circ16'\text{E}$ . The general bathymetry around the region is quite rugged. A couple of abyssal hills are also located in the vicinity. The area away from the seamount is comparatively plain. The mount was surveyed in detail using a narrow beam sounder (NBS) and a deep-sea sounder (12 kHz) run simultaneously. The NBS has distinct advantages over conventional sounders in delineating features on the seabed (Belderson, Kenyon, and Stride 1972). The NBS recorder was adjusted to a 4000–6000 m range to obtain an enhanced resolution of the seabed. Seven east-west lines about 25 nautical m long and two cross lines were selected, which traversed the entire seamount. The distance between the east-west lines was 3 nautical miles. For accurate navigation, the Integrated Navigation System (with Magnavox dual-channel satellite navigator) was employed.

### Methods

Echo-sounding data collected during this survey and also from the previous cruises were used for preparing the depth contour map of the area. Echo-sounder records were digitized, interpolated, and merged with navigation data on a Norsk Data computer using the GMS (Geco mapping system) package. A contour map and isometric display of the seamount were also prepared using this package. Slope angles were computed using depth values for different lines, and a slope angle map of the area was prepared.

### Results and Discussion

Unlike the majority of the seamounts from the Pacific Ocean (Meteor, Koko, etc.), this is not a flat-topped Guyot. The basal extension of the mount is 24 km and the maximum height is 1275 m. The area covered by the mount is about 189.7 sq km. Two features, a seamount and an abyssal hill that lie side by side, are evident from the contour map and isometric display (Figures 1 and 2). The bathymetric profile along some of the lines across the seamounts is shown in Figure 3. Mean, maximum, and minimum depths in each line and entire area are tabulated in Table 1. Line 4 has minimum mean depth of 4975 m. On either side of the mount, the depths may extend down to about 5400 m. In general, the average depth of the entire area is 5214.1 m. The southernmost part of the seamount appears on line 3 with a maximum height of about 250 m. The peak of the mount in line 4 is about 1275 m. In this profile the western flank of the mount appears to be gentler and lengthier, whereas the eastern flank is steeper and smaller in basal extension. On the northern side of this profile along line 5, the seamount has a height of 600 m. Along line 6, two features are evident (at heights of 800 m and 600 m). The feature at  $76^\circ21'\text{E}$  on this line appears to be the extension of the seamount, whereas another feature at  $76^\circ12'\text{E}$  is another abyssal hill. The morphology of the mount also appears to be in this line as the eastern side is steeper compared to the western side. At about 250 m

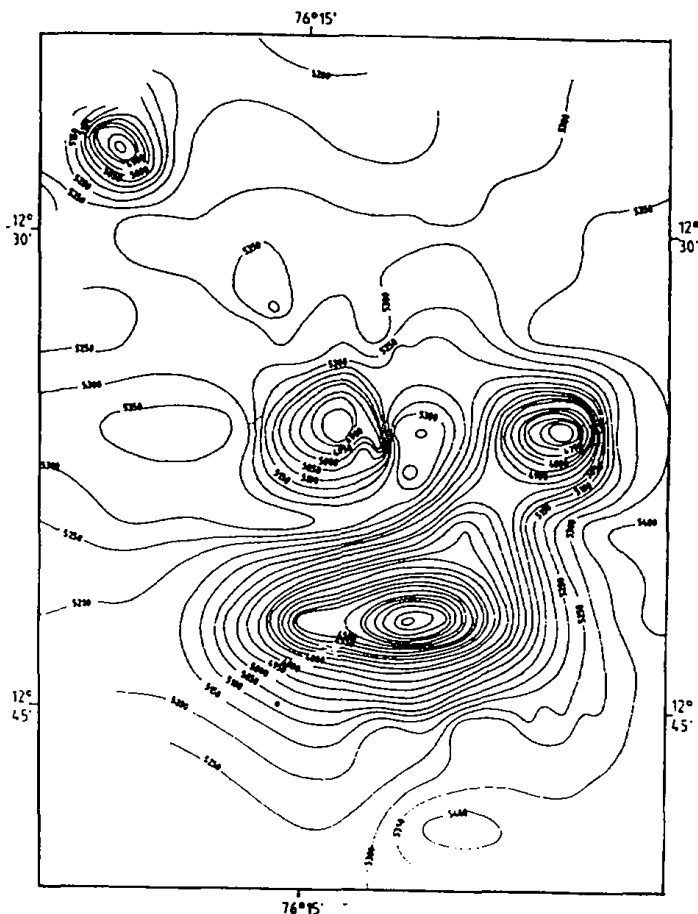


Figure 1. Depth contour map of seamount.

down, there is the conspicuous presence of a flat flank on the western side. This seamount appears only as a small signature on line 7 (up to 75 m only) along with the other abyssal hill. Thus that seamount appears on lines 3, 4, 5, and 6. Little evidence could be gathered from bathymetric profiles across the seamount to indicate faulting. Also, from the profiles and contour map, it could be concluded that the trend of the seamount is approximately NNE-SSW.

The contour map (Figure 1) with a contour interval of 50 m shows a pair of steep positive features, along with an abyssal hill height of 550 m on the top left-hand corner of the map (lines 7 and 8). Dredging carried out on this mount has yielded ferromanganese encrustations on basalts.

Slope angles were also computed on all lines. The mean maximum and minimum slope angles for each line are listed in Table 1. The slope angle contour map is presented in Figure 4. Mean slope for the entire area is  $2.85^\circ$ , much higher than the average of  $1.305^\circ$  reported elsewhere in the Central Indian Basin (Kodagali 1989). Lines 4 and 6 where the peak of the seamount is encountered reported higher mean angles. The frequency of occurrence of different angle ranges in different lines are tabulated in Table 2. Lines 4, 6, and 9 show less occurrence of  $0-1^\circ$  angles, whereas steep angles (over  $7^\circ$ ) appear about 20% of the time. For the entire area, 45% of the angles were found to be in the range  $0-1^\circ$ . Steeper angles with over  $7^\circ$  appeared 15% of the time; the rest were in the range  $1-7^\circ$ .

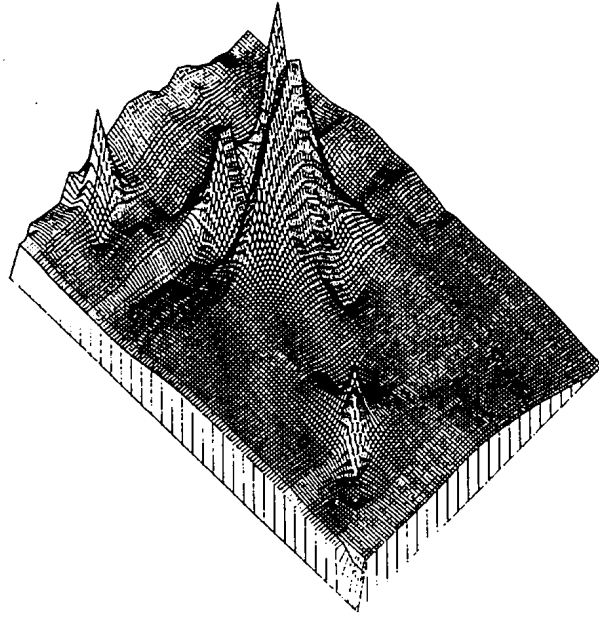


Figure 2. Isometric view of seamount.

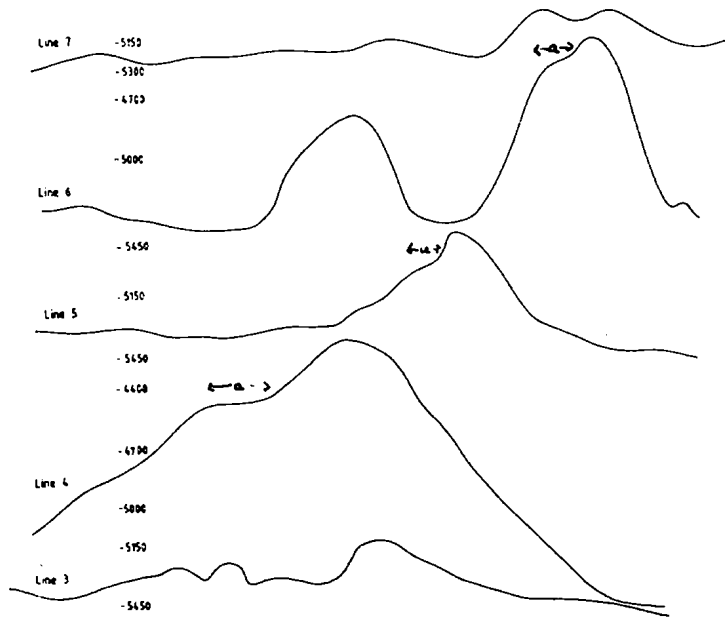


Figure 3. Bathymetric profiles across lines 3-7. Note the steplike feature in profiles 4, 5, and 6.

**Table 1**  
Mean, Maximum, and Minimum Depth and Slope Angles

Line No.	Depth			Slope Angle		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
2	5392.4	5432	5000	1.1	4.68	<1.0
3	5301	5401	5000	2.37	10.58	<1.0
4	4975.5	5416	4114	3.55	13.48	<1.0
5	5250.3	5408	4796	2.11	9.16	<1.0
6	5082.4	5387	4466	5.55	27.97	<1.0
7	5276	5395	5000	2.21	12.46	<1.0
8	5266	5370	4790	1.67	14.29	<1.0
9	5266.3	5420	4699	4.09	35.1	<1.0
Entire area	5214.12	5420	4114	2.85	35.1	<1.0

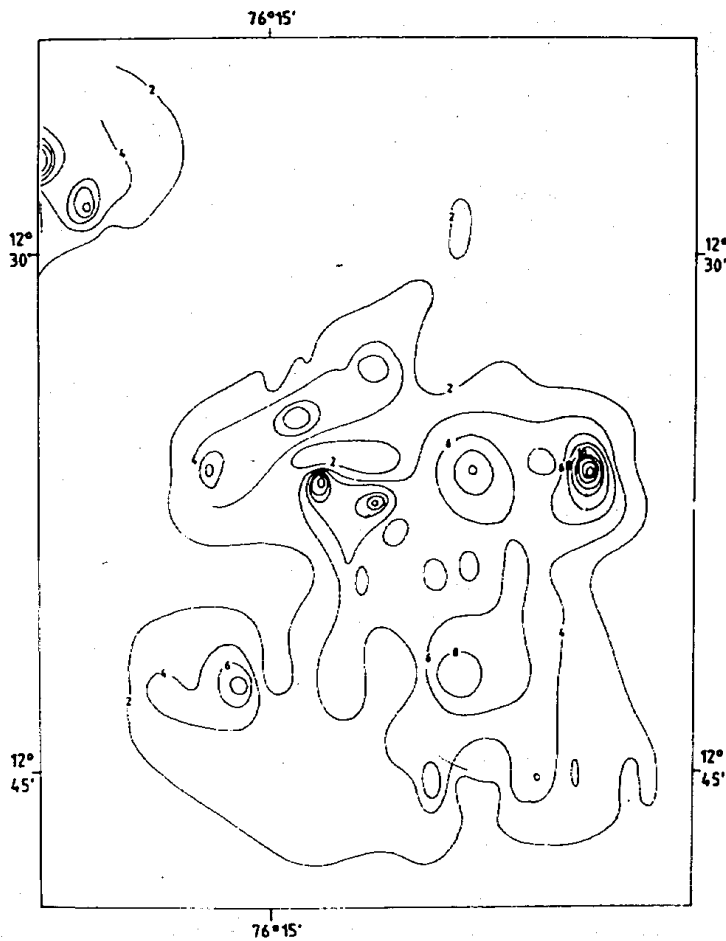


Figure 4. Slope angle map for the seamount area.

**Table 2**  
Frequency Percent for Angle Ranges

Line No.	0-1	1-3	3-5	5-7	over 7
2	56.87	38.63	4.54	0	0
3	38.46	35.89	12.82	5.12	7.7
4	23.68	30.26	21.05	5.26	19.73
5	54.0	18.0	16.0	4.0	8.0
6	32.5	15.0	22.5	10.0	20.0
7	52.0	22.0	14.0	4.0	8.0
8	63.3	20.0	7.7	4.44	4.4
9	38.14	27.83	9.27	3.09	21.65
Entire area	45.32	25.87	12.47	4.22	12.11

This seamount is far away from land, and the sedimentation rate is less in this region. Hence the mountain seems to be less eroded than might be expected, and there is no flat top, which can also be attributed to this fact. Pacific Ocean guyots are developed by wave action and reef growth when features are near the surface (Pratt 1963). The seamount heights are generally related to the age of the lithosphere (Morov 1982). As the Central Indian Basin is comparatively young, seamount height in this region is obviously less. The seamount trend is perpendicular to the mid-Indian ridge and parallel to fracture zones. The Chagos fracture zone, which is nearest to this area, is a transform fault of early Tertiary age. The present plate positions result from Miocene, recent openings along a N-S fracture zone that existed in this area during the interval of rapid spreading in the late Cretaceous to early Tertiary period (Fischer, Sclater, and McKenzie 1971). Volcanism initiated by the leaky open transform faults might have resulted in the seamount. It might have later subsided because of effects of seafloor spreading. A subsidence in the Central Indian Basin is indicated by the results of DSDP site 215 (Borch et al. 1972). In the Pacific Ocean, the response of the seamounts to subduction-related tectonic processes is a function of two factors—seamount age and degree of fracturing of the surrounding seafloor as the oceanic plate bends prior to subduction (Fryer and Smoot 1985). Smaller mounts (<40 km diameter) are disturbed as much or more than the surrounding area. Larger mounts over 40 km diameter show less evidence of fracturing prior to subduction. This seamount has a maximum diameter of about 24 km and the seafloor around it is quite rugged with varying slope angles. Batiza (1982) suggested that features having nonlinear distribution are consequences of ocean lithospheric evolution. It is likely that nonhotspot volcanoes are preferentially located on fracture zones. Some midplate seismic activity may be associated with fracture zones (Okal, Talandier, Sverdrup, and Jordan 1980) that theoretically are supposed to be inactive.

### Summary

The uncharted seamount reported here has a height of 1275 m and is an isolated feature. This conical mount has a steep eastern flank and a gentle western flank with a steplike feature on the western flank. The trend is approximately NNE-SSW. Profiles across the seamount show little evidence of faulting, though the general topography around the

mount is quite rugged. The mean depth is less and the mean slope angle is higher than the average reported for the region. Slope angles in the area range from  $< 1$  to over  $35^\circ$ . Dredging on the mount has yielded ferromanganese encrustations on the basalts. Mid-late volcanism initiated by leaky open transform faults might be the cause of this feature. However, detailed studies using multibeam sonars, magnetometers, and gravimeter coupled with geochronological studies might throw more light on its origin.

### Acknowledgments

The author gratefully acknowledges the constant guidance, encouragement, and critical comments on the manuscript received from R. R. Nair, project leader, Polymetallic Nodules Surveys project. Thanks to B. N. Desai, director, and P. S. N. Murthy, head of the Geological Oceanography Division for the facilities provided. The work was carried out with financial support from the Department of Ocean Development, government of India under its Polymetallic Nodule project.

### References

- Batiza, R. 1982. Abundances, distribution and sizes of volcanoes in the Pacific Ocean and implications for the origin of non hotspot volcanoes. *Earth and Planetary Science Letters* 60:195-206.
- Belderson, R. H., N. H. Kenyon, and A. H. Stride. 1972. Comparison between narrow-beam and conventional echosounding from Mediterranean Ridge. *Marine Geology* 12:M11-M15.
- Borch et al. 1972. *Site 215 DSDP Report*, Vol 22. Washington, D.C: U.S. Govt. Printing Office, pp. 193-200.
- Davies, T. A., P. Wide, and P. A. Clague. 1972. Koko seamount, a major guyot at the southern end of Emperor seamount chain. *Marine Geology* 13:311-321.
- Fisher, R. L., J. G. Sclater, and D. P. Mckenzie. 1971. Evolution of central Indian ridge, Western Indian Ocean. *Bull. Geol. Soc. of America* 82(3):553-562.
- Frazer, J. Z., and L. L. Wilson. 1980. Manganese nodule resources in Indian Ocean. *Marine Mining* 2(3):257-292.
- Fryer, P., and N. C. Smoot 1985. Process of subduction in Mariana and Izu Bonin trenches. *Marine Geology* 64:67-90.
- Gould, W. T., R. Hendry, and H. E. Huppert. 1981. An abyssal topographic experiment. *Deep Sea Research* 28:409-440.
- Handschumacher, D. 1973. Formation of the Emperor seamount chain. *Nature* 244(5412):150-152.
- Horn, D. R., B. M. Horn, and M. N. Delach. 1973. Factors which control distribution of ferromanganese nodules and proposed research vessel tracks in N. Pacific. LDGO Tech. Rep. No. 8, pp. 1-2.
- Irish, J. D. 1976. Bathymetric and Magnetic survey of California seamount. *Marine Geology* 21(3):M31-M35.
- Kodagali, V. N. 1988. Influence of regional and local topography on the distribution of polymetallic nodules in Central Indian Ocean Basin. *Geo-Marine Letters* 8(3):173-178.
- Kodagali, V. N. 1989. Morphometric studies on a part of Central Indian Ocean. *Journal of Geological Society of India* 33(6):547-555.

- Larina, N. I. 1975. Mountains of the Pacific Ocean. *Oceanology* 15(1):89-94.
- Morov, N. A. 1982. Relationship between height of Pacific seamount and age of lithosphere. *Oceanology* 22(3):320-324.
- Okal, E. A., J. Talandier, K. A. Sverdrup, and T. H. Jordan. 1980. Seismicity and tectonic stress in South Central Pacific. *Journal of Geophysical Research* 85:6479-6485.
- Pratt, R. M. 1963. Great Meteor Seamounts. *Deep Sea Research* 10:17-25.
- Walgate, R. 1984. Excitement on the seabed. *Nature* 311 (5982):96.