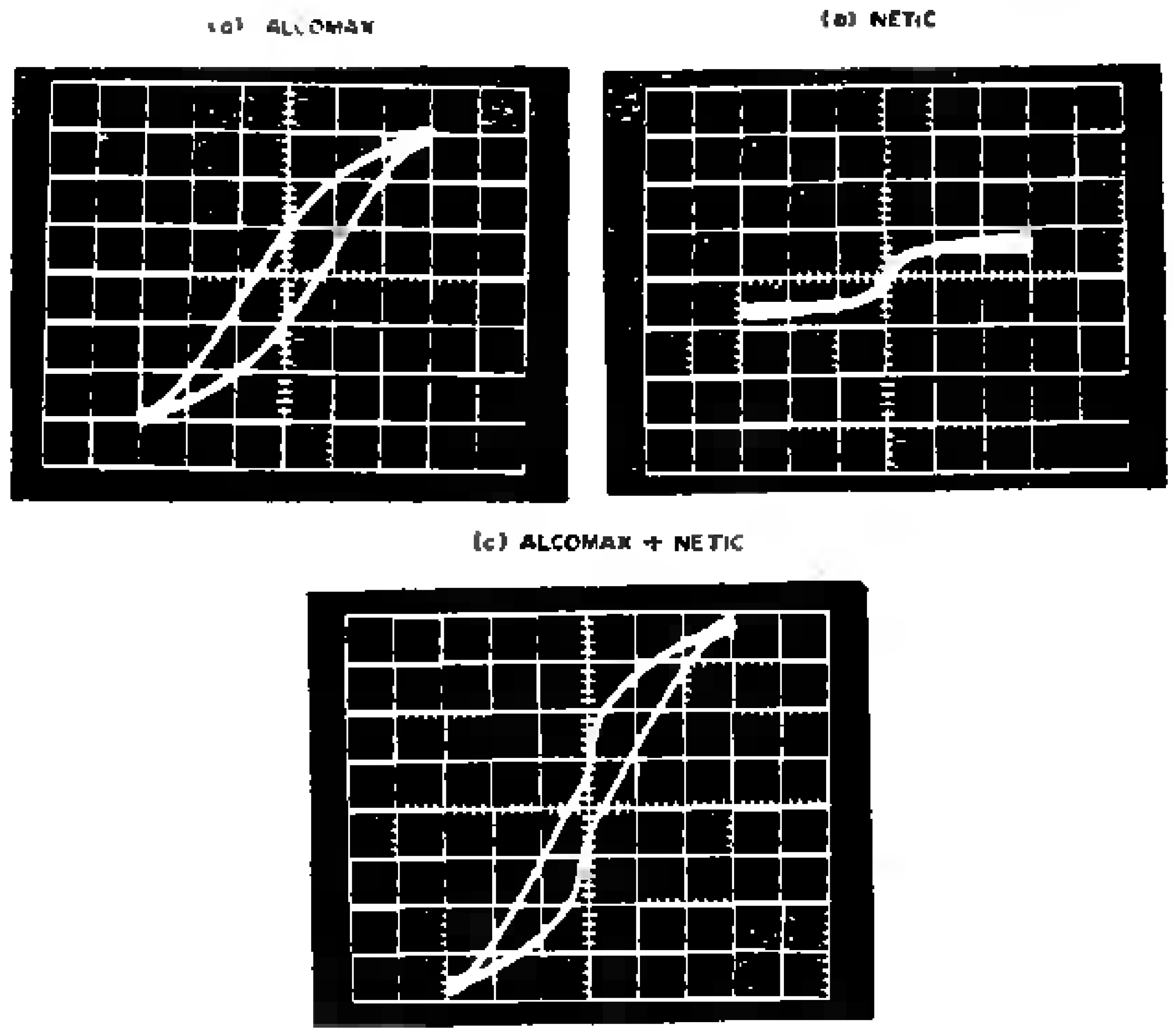
of the sample, particularly in cases where the samples concerned are mixtures of minerals which would be characterized by weaker magnetic interactions of the inter-constituent type. On the other hand, when the individual constituents used in the mixtures are strongly magnetic such as the high coercive and high permeability substances, Alcomax, mu-metal or other shielding materials, *e.g.*, Netic and Co-Netic, the algebraic summation of individual loops may not hold strictly on account of the large interactions between the individual substances. Nevertheless, a strong qualitative agreement in the case of such substances has been observed experimentally and also graphically.



HORIZONTAL AXIS 1 SMALL DIV = 160 OSTD
VERTICAL AXIS 1 SMALL DIV = 1 E.M.U

FIG 4

A typical set of loops for such commercial substances is shown in Fig. 4. The composite loop of Fig. 4, c shows a constriction whereas the loops for individual constituents (Alcomax and Netic, Fig. 4, *a* and *b*) are normal.

One may hope that a better understanding of the magnetic interactions between components having widely different magnetic properties in a mixture may render the explanation of even other types of abnormal loops possible.

Further studies of this type with a large variety of minerals and alloys are underway and will be reported in due course.

We thank Prof. D. Lal for his keen interest and encouragement throughout this work. We would also like to record our grateful thanks to Dr. R. V. S. Sitaram of the Linear Accelerator Group (T.I.F.R.) for several valuable discussions and suggestions.

1. Scherb, M. N., *Rev. Sc. Inst.*, 1948, **19**, **411**
2. Oguey, H. J., *Ibid.*, 1960, **31**, **701**.
3. Bruckshaw, J. Mac. and Rao, B. S. R., *Proc. Phys. Soc.*, 1950, **63 B**, **931**.
4. Likhite, S. D., Radhakrishnamurty, C. and Sahasrabudhe, P. W. (in preparation).
5. Elmen, G. W., *Jour. Franklin Instt.*, 1928, **206**, **336**.
6. Smit, J. and Wign, H. B. J., *Ferrites*, Phillips Tech. Lib., 1959, p. 311.
7. Takasu, S., Chiba, S., Hirose, Y. and Kurihara, K., *Jour. Phys. Soc. Japan*, Kyoto Conf., 1961, **17**, Supp. B-I.
8. Kienlin, Par A. De, Kornetzki, M. and Rabl, H., *Colloque International de Magnetisme*, Grenoble, July 1958, p. 183.

HEAVY MINERAL INVESTIGATIONS IN NAHAN SERIES NEAR NAHAN, HIMACHAL PRADESH

R. N. SINHA AND K. N. KHAN

Petrology Laboratory, Oil & Natural Gas Commission, 37-A, Curzon Road, Dehra Dun

Introduction

THE heavy mineral suite of Nahan Series exposed approximately six miles east of Nahan (30° 34′ : 77° 18′; Survey of India Topo Sheet No. 53 F/6, Himachal Pradesh) along Bata Nala (30° 21′ 50″ : 77° 24′ 20″ to 30° 34′ 30″ : 77° 24′ 10″) has been studied. Such studies have been found useful for attempting local correlation of Siwalik rocks.[2,6] The Nahan Series are devoid of sufficient polospore or faunal assemblages for correlation and age determination. They, however, are correlated with Lower Siwaliks on the basis of lithologic characters.[1]

The Nahan Series of the type area around Nahan is correlated with Lower Siwaliks mainly on basis of lithologic characters.[3-5,7] According to Pascoe[5] the Nahan Series exposed in the neighbourhood of Haritalyangar (31° 32′ : 76° 43′) has yielded *Conohyus chinjiensis* Pilg.,

* Published by the kind permission of Director of Geology, Oil & Natural Gas Commission. The views expressed are that of authors and not necessarily of Oil & Natural Gas Commission. Measured Section was sampled by Shri G. C. Agarwal, Geologist, and Party during field season, 1960-61.

which is characteristic of Chinji (Upper Tortonian).

The Nahan Series forms a 4,475 ft. thick sequence (Fig. 1) and is part of the autochthonous belt of Himalayan foothills. They are separated from the Upper Siwaliks (Astian to Cromerian) by Paonta Thrust towards the south and from the older as well as pre-Tertiary rocks (Subathu-Auversian to Bartonian and Dagshai-Aquitanian†) by Nahan Thrust towards the north. They are mostly grey coloured, hard, medium grained, micaceous argillaceous and occasionally calcareous sandstones. Sometimes the sandstones contain intraformational clay-conglomerates and are harder, indurated as well as fractured nearer the thrusts. The associated clays are silty and rarely mottled and of reddish-brown, bright red and cherry-red colours (Fig. 1). Streaks of lignite are traceable.[1]

HEAVY MINERAL RANGES IN NAHAN SERIES, NAHAN (H P)

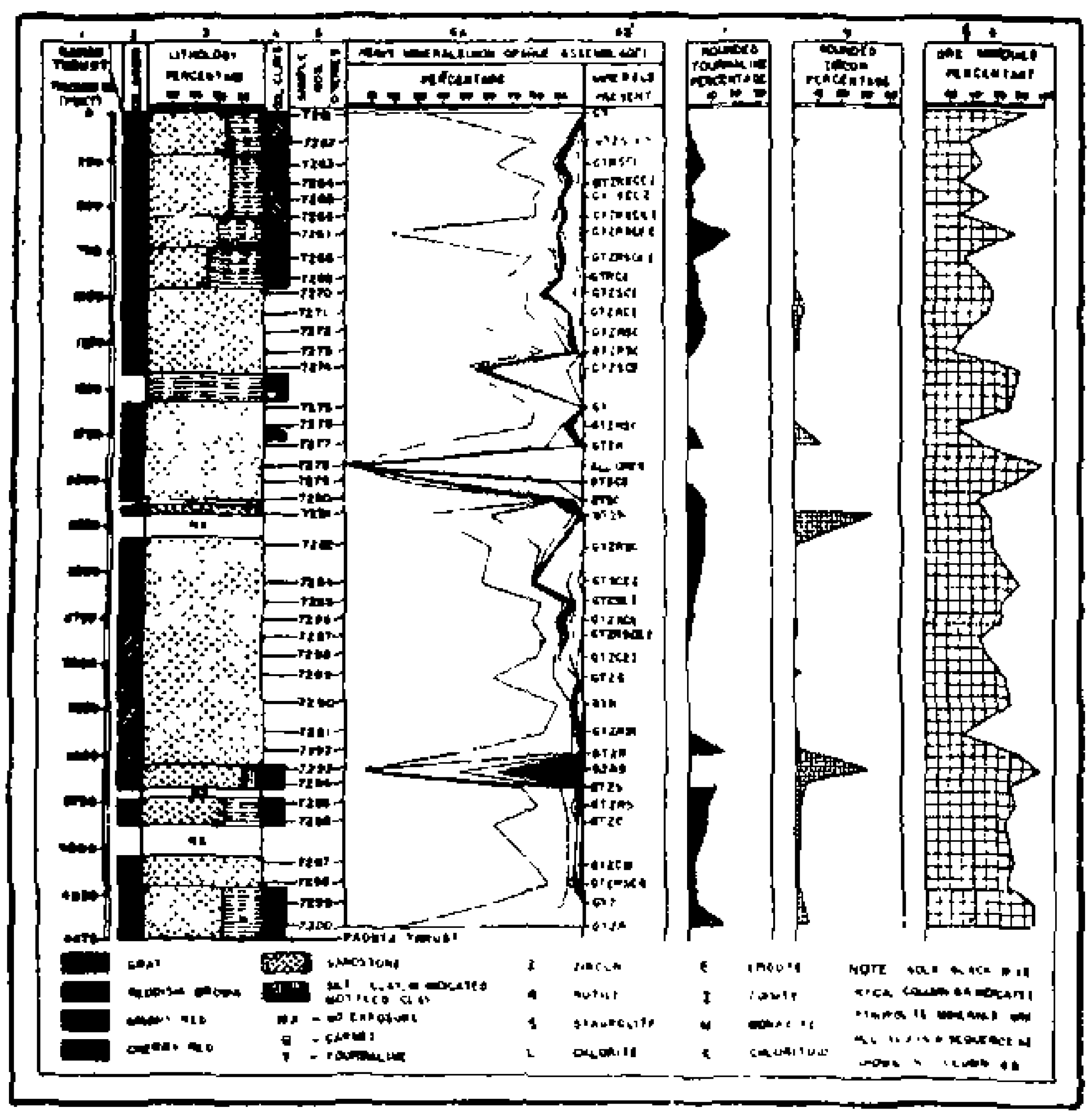


FIG. 1

Heavy Mineral Study

A total of 39 samples (mainly sandstones), collected at 100 feet stratigraphic interval, were treated to isolate heavy minerals. Disintegration of samples was achieved by soaking in water and treatment with boiling N/10 HCl. After washing (to remove clays) and subsequent drying, the sand fraction was sieved to get a fraction of 88 to 250 microns grade.‡ The heavy minerals were separated from this fraction by using bromoform (sp. gr. 2·9). They were first studied in liquid mounts for qualitative estimations and later counted for quantitative estimations. The percentage of various components is presented in Fig. 1. A total of ten heavy minerals is recognized. Only seven of these are persistent. The more common include abundant to fairly abundant garnet; common to very common tourmaline; scarce to common epidote, staurolite, chlorite and zircon and rare to scarce rutile. The rest include zoisite, chloritoid and monazite. Ore minerals are fairly abundant. The general characters of more common heavy minerals are as given below:

Ore Minerals.—Include angular to subrounded opaque minerals. Magnetite is dominant. Hematite and pyrite are comparatively rare.

Garnet.—Usually pinkish and/or colourless, less frequently brownish, angular to subrounded, fractured, pitted and contain inclusions of quartz and ore minerals. Some show strain shadows and are pseudoisotropic.

Tourmaline.—Usually brown to light brown and yellow, strained, subangular to subrounded, fractured and contain inclusions of quartz. A few, though rare, show good rounding.

Epidote.—Generally colourless or light greenish, angular to subrounded and fractured.

Staurolite.—The most common are straw-yellow to reddish-brown, angular to subrounded and with hackly fractures and inclusions.

Chlorite.—Green to pale green and contain inclusions of ore minerals (usually magnetite ?).

Zircon.—Colourless to brown, subrounded and fractured.

Rutile.—Usually red, less frequently yellow, subangular to subrounded and fractured.

Comparison with Lower Siwaliks

Recent investigations of heavy mineral suites have shown that the Lower Siwaliks of Jwalamukhi and neighbouring areas in Punjab are characterized by presence of yellow tourmaline and staurolite.[2] Kyanite characterises Middle Siwaliks of Punjab[6] and thus helps in differentiating them from Lower Siwaliks. Pre-Siwaliks of Punjab and Himachal Pradesh are recognised by presence of barite and absence of both kyanite and staurolite.[6] A comparison of the heavy mineral suites of Lower Siwaliks and Nahan Series exposed along Bata Nala indicates that they are quite similar to one another.

† After Krishnan, 1960, table 66, p. 499.

‡ Prolonged experimentation has shown that this fraction yields a fairly large and representative heavy mineral residue.

Both are characterized by presence of staurolite and absence of kyanite. Heavy mineral residues, hence, offer an additional criterion for correlating Nahan Series with Lower Siwaliks.

Provenance

The light crop (fraction with sp. gr. less than 2·9) contains igneous and metamorphic quartz along with some feldspars. The heavy mineral suites also consist of index metamorphic minerals (*e.g.*, epidote, garnet and staurolite) besides others (*e.g.*, tourmaline, zircon and rutile) which could only be derived from igneous rocks. Reworking of minerals is absent. The sandstones are texturally immature and poorly sorted. They contain a good percentage of unstable detrital components (*e.g.*, shaly and schistose rock fragments, chlorite and micas) as well as argillaceous matter. Most of the detrital components are subangular to subrounded and thus do not indicate long-distance transportation. It appears that the sediments were derived from igneous and metamorphic rocks exposed in the nearby area (possibly Himalayan region) and deposited probably in a shallow unstable basin.

Conclusion

The Nahan Series of Bata Nala Section, which has been already correlated with Lower Siwaliks on basis of lithologic characters, is unfossiliferous. The present study indicates that its heavy mineral suite is comparable to that of Lower Siwaliks providing additional criteria for correlating the two. The provenance appears to have been near the place of deposition and it consisted of igneous and metamorphic rocks.

Acknowledgement

The authors are highly obliged to Shri P. V. Dehadrai, Superintending Geologist, O.N.G.C., for encouragement and critical remarks and to Messrs. G. C. Agarwal, R. N. Mitra and S. N. Sikka, Geologists of O.N.G.C., for discussions and permission to include some of their field observations.

1. Agarwal, G. C., O.N.G.C. Directorate of Geology, (Unpublished Report), **1961**, p. 1.
2. Dehadrai, P. V., *Quart. Journ. Min. Met. Soc. India*, 1958, **30**, 211.
3. Heron, A. M., *Rec. G.S.I.*, 1936, **71**, 19.
4. Krishnan, M. S., *Geology of India and Burma* (4th Edition), Higginbothams (Pvt.) Limited, Madras, 1960, p. 499.
5. Pascoe, E. H., *A Manual of Geology of India and Burma*, Government of India, 1963, **3**, 1789.
6. Raju, A. T. R. and Dehadrai, P. V., *Curr. Sci.*, 1962, **31**, 378.
7. Wadia, D. N., *Geology of India*, 3rd Edition (Revised), Macmillan & Co., Ltd., London, 1957, p. 366.

THE INTERIOR OF MARS

There are marked differences between the internal structure of the four inner or terrestrial planets—Mars, Earth, Venus and Mercury—and the major planets Jupiter, Saturn, Uranus and Neptune. The terrestrial planets are solid bodies whereas the major planets are largely, if not entirely, gaseous. Of the terrestrial planets only the structure of the Earth can be directly investigated. However, by assuming that these planets are all composed of similar materials it is feasible to build a picture of their possible structure.

Such a study using simple hydrostatic theory and certain geophysical characteristics of the earth has recently been made by Professor R. A. Lyttleton for Mars and Mercury. Structurally, the Earth may be divided into three principal zones—a liquid core surrounded by two zones of solid material. Mars has no liquid core and a model for Mars need only have two zones. Lyttleton's study leads to the following broad results regarding the interior of Mars: It should have a solid core containing 53 to 82% of the planet's mass. The predicted radius lies between 3355 and 3418 kilometres, thus confirming the presently known value of 3380 kilometres. If Mars had heated up slightly since its formation, some expansion of the planet would have resulted. Some rifting of the planet's surface—but no mountain forming—would be expected. —(*Science Journal*, April 1965.)