The composition of arsenopyrite, especially S/As ratios as determined by d_{131} spacing (1.6354 Å) is confirmed by chemical analysis (Fe = 33.6%, As = 47.9%, S = 18.5%). In the Fe-As-S system d_{131} spacing is a measure of S/As ratio of arsenopyrite. The temperature of formation is 430 ± 15°C. This indicates that the confining pressures did not exceed 1 bar (Clark, 1960) in Kolar.

The absence of wollastonite in the gold-quartz veins of Kolar and the presence of calcite-quartz association, formed under middle amphibolite facies conditions, also suggests that carbon dioxide pressure was low during ore formation.

Conclusions: The whole rock ages (isochron) and the mineral ages of the Precambrian formations in the area indicate that the Dharwars were laid down on the basement gneisses, which were recrystallised during the infolding of the belt. The refolding of the belt caused depletion, migration and localization of the ore constituents along the crests following the pressure gradients along the fold. The mineral assemblage studies suggest that they were all formed under low P_{S_2} P_{CO_2} and confining pressures during the middle amphibolite facies conditions.

Acknowledgements: We thank Prof. V. S. Venkatasubrahmanyam and co-workers, Department of Physics for the mineral and the whole rock ages of the area.

Our thanks are also due to the Government of India and the Managing Director, Kolar Gold Mine Undertakings, for permission and co-operation to carry out the investigations.

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THE OCCURRENCE OF ROCKS OF KAKARA (PALEOCENE) AFFINITY IN THE BAKHALAG—BUGHAR BELT, HIMACHAL PRADESH

S. V. SRIKANTIA AND R. P. SHARMA
Chandigarh

Introduction: In the course of mapping of parts of Lower Himalayas in the Himachal Pradesh, the authors found a continuous strip of hitherto unreported fossiliferous limestones and shales of Kakara affinity (Srikantia and Bhargava, 1967), between Bakhalag (31°9′25″ : 76°56′40″) and Bughar (31°17′ : 76°56′40″) in Arki tehsil of Mahasu district. The belt extends over a length of about 14 km in the north-south direction and is about one to two kilometres broad. It is involved in a

very complicated tectonic set up of a *schuppen* type. On the basis of lithological association and fossil assemblage the lithofacies are correlated with the Kakara series.

Geology : The sediments of Kakara series are seen to overlie certain pre-Tertiary unfossiliferous limestones, dolomites and shales and also volcanics, referred to hereafter as Darla Volcanics, along a profound unconformity. At places the contact is marked by the presence of pisolitic laterite. Variegated shales and limestones are the dominant lithofacies; and further, it is characterised by the presence of phosphatic nodules and phosphatic limestone.

The shales are green, grey and purple in colour. They are highly incompetent, poorly laminated and friable. At places they are phyllitised. The shales simulate the characteristics of the older pre-Tertiary shales and also the shales of the Subathu series on the sub-thrust side. This makes the separation of shales belonging to different formations at times an embarrassingly difficult task, though the overall association makes it less arduous to recognise them. Green shales contain siltstone intercalations. There are also thin horizons of purplish to white quartzitic sandstone. Shales are locally carbonaceous as at Ladhi. There are sporadic purple shale intercalations within the green shale facies.

In thin sections, the shales are composed of clay minerals which show various stages of diagenesis into chlorite, sericite and muscovite. In some sections shales contain poorly dispersed collophane ovulites and chert fragments. The interbanded siltstone beds are composed of 52% quartz of 20 micron average size which are angular to sub-rounded in shape. 40% of matrix includes primarily incipient chlorite and microsiliceous matter. Iron ores, epidote, glauconite and staurolite are some of the accessory minerals.

Limestone occurs as lenticular bands within green shales. There are two types. (1) fossiliferous limestone, (2) fossiliferous phosphatic limestone. Fossiliferous limestone is composed of 50% cryptocrystalline calcite and 40% replaced foraminiferal tests. The rest 10% constitutes silt-grade quartz which is mainly detrital and is enclosed in lime mud matrix. Fossiliferous phosphatic limestone occurs in the form of lenses and outcrops closely interbanded with the green shales. These beds vary in length from a few metres to 900 metres as along Kalti-Jau ridge, and vary in thickness from a few centimetres to two metres. They always show general lateral pinching. On a fresh surface the limestone is blue gray in colour and is generally weathered to greyish brown outcrops. Phosphate occurs in them in the form of pellets, coprolites and ovulites, and also as replaced test fragments. Bulk samples of limestone contain about 2 to 4 per cent P_2O_5. Pyrite, limonite, haematite and glauconite are some of the accessory minerals in the limestone.

The green shale-limestone association is succeeded by dirty grey shales which are extensively bleached. On the surface of the outcrops there are rusty brown stains. The shales are highly incompetent and poorly fissile. They enclose phosphatic nodules which range in size from granules to boulders. They contain 20 to 25% P_2O_5. Sporadically nodules of pyrite are also seen within these bleached shales. Opaque ore minerals, epidote, zircon, garnet, staurolite, tourmaline, actinolite, barite and rutile are the important heavy minerals present in the green shale facies. They have definite metamorphic provenance. The presence of glauconite and also the

association of phosphatic nodules suggest a continental shelf deposition of these sediments in a shallow marine basin.

Structure: The area in which the sediments of Kakara series occur offers a very complicated structural pattern. The Kakara beds together with their pre-Tertiary basement rocks are thrust over the Subathus of the main para-autochthonous belt. In the course of thrusting, it appears the basement limestone-dolomites sliced off and have, in turn, ridden over the younger Kakara sediments along close imbricates, thereby presenting a *schuppen* structure. The process of thrusting has affected the competent limestone-dolomite rocks and the highly incompetent Kakara rocks differently, and this has resulted in a chaotic geometry of the structure. The structural

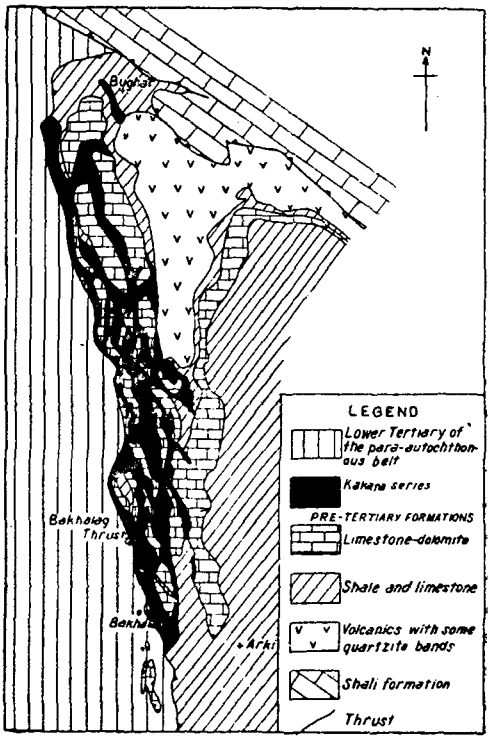

Figure 1. Sketch geology of the area between Bakhalag and Bughar.

complication has resulted to some extent in the mixing up of Subathu rocks of the para-autochthonous belt with that of Kakara rocks. Regionally the structure of the area is a main antiform with the Darla volcanics occupying the core and the axis trending north-south, which is further cross folded along a northwest-southeast axis of the main Simla synform in the Simla Hills. In the western part of the area, where the Kakara sediments are mainly deposited, they are folded together with the older basement rocks into a synform and thrust over the para-autochthonous foot-hill belt of Tertiary along the Bakhalag thrust (i.e. the so called boundary fault of O.N.G.C.). In this synformal region *schuppen* structure has developed. In the north, this belt is overlapped by the Tattapani digitation of Shali belt along a thrust.

Fossil assemblage: Sample of dark grey shali limestone and hard grey limestone were collected from various localities of Kakara series for palaeontological study. B. C. Verma of the Geological Survey of India has made the following faunal identifications from these samples:

(1) Bakhalag area: *Assilina* sp. aff. *A. subspinosa* Davies and Pinfold. The tests of specimens are, however, comparatively much smaller than the ones reported from Salt Range (Sakesar limestone). *Dictyoconoides* sp. indet., *Operculina* sp. indet.

(2) East of Kog: *Operculina* sp. indet., *Dictyoconoides* sp. indet., *Nummulites* sp. indet., *Assilina granulosa* d'Archaic, *Operculinoides* sp. indet., *Gumbelina* sp. indet., *Cibicides*? sp. indet., *Ellipsobulimina* sp. indet. and crushed lamellibranch shells.

(3) Dhynpur: One doubtful specimen of *Nonionella* sp. indet. and broken shells of lamellibranch.

(4) South of Sherpur: *Dictyoconoides flemingi* Davies and Pinfold. *Operculina* cf. *Salsa* Davies and Pinfold, *Operculina* sp. indet. *Nonion* sp. indet. and a specimen of ostracod.

(5) Talav: *Dictyoconoides* cf. *flemingi*, *Operculina* sp. indet. and a single but well preserved tooth of fish. Numerous other unidentifiable forms are also present.

(6) Near Kolka: *Operculina* sp. indet., crinoid stems, *Cibicides* sp. indet. and some other obscure forms of foraminifers.

(7) Raur: *Cibicides* sp. cf. *C. lobatulus*? (Walker and Jacob), minute broken gastropod shells and-a few other poorly preserved forams.

(8) West of Goah village: *Cibicides* sp. indet., *Nonion* sp. indet. and *Operculina* sp. indet.

(9) Near Darlaghat: Thin sections show some radiating structures of algae? and sections of lamellibranch shells.

Age: The presence of *Dictyoconoides flemingi* in the limestone beds is suggestive of a Ranikot (Paleocene) age for the beds, and together with other faunal assemblage these beds, perhaps, have a range of Upper Ranikot to Lower Laki. A more specific identification of the species will eventually enable to fix the exact range of these beds. Lithologically these beds bear a close resemblance with the Kakara rocks of the Kakara-Chapla group of villages (Srikantia and Bhargava, 1967). The authors suggest a detailed palaeontological investigation of this newly discovered fossiliferous horizon.

Acknowledgements: The authors thank Mr. B. C. Verma for identifying the fossils. The help received from Messers R. N. Srivastava and S. E. Hasan in writing some aspects of geology is gratefully acknowledged.

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