DISCOVERY OF FOSSIL ALGAE FROM THE SINGTALI LIMESTONE AND ITS BEARING ON THE TECTONIC SET UP OF THE GARHWAL NAPPE

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ABSTRACT

An oolitic, shell bearing limestone band occurs as part of the northern limb of Garhwal Syncline exposed on the right bank of the Ganga, on the Rishikesh Devprayag motor road, at the suspension bridge near the village of Singtali. The limestone has yielded a rich assemblage of algal and associated microfossil remains. The following forms of algal remains have been recognised from this limestone band: *Anatolipora* Konishi, *Anthracoporella* Kachansky & Herak, *Eogoniolina* Endo, *Epimastopora* Pia, *Gyroporella* Gümbell, *Mizzia* Schubert, *Oligoporella* Pia, *Pseudoepimastopora* Endo, *Ortonella* Garwood, *Succodium* Konishi, *Anchicodium* Johnson, *Gymnocodium* Pia, *Permocalculus* Elliott, *Parachaetetes* Deninger and *Hikorocodium* Endo. The above algal flora suggests a Permian age for this limestone.

INTRODUCTION

AUDEN, while working in Himachal Pradesh on Krol belt, mapped a sequence of shale, sandstone, quartzite and grit with a dark sandy limestone which rested on his Krol Series and formed the highest unit of his Krol Syncline. He (1934) correlated this with the Tal beds described by MIDDLEMISS (1887) in Garhwal and called them the Tal Series. Later (1937), while working in Garhwal area AUDEN (1937) revised MIDDLEMISS's mapping and recognised the existence of the thrust sheets in the area namely, the Amri Nappe and the Bijni Nappe. He grouped the two as Garhwal Nappe. He further suggested that this Garhwal Nappe rested on rocks of an underlying unit which was the same as the Krol Nappe mapped by him earlier in Himachal Pradesh and Mussoorie area. He correlated the marine limestone, volcanic breccia and purple slates to Krol and Blaini Series, respectively. AUDEN (1934, 1937) also suggested Jurassic to Cretaceous age for the Tals. This was also accepted by later workers namely TEWARI AND KUMAR (1967), RAVI SHANKER (1971), SHRIVASTAVA (1972) and MAITHANI (1972). It may be mentioned here that the topmost member of the Tals in the Garhwal area comprised an oolitic limestone containing numerous shell fragments. This has been mapped to occur intermitently all around the crystalline nappe of the Garhwal Syncline. Its best and easily approachable outcrops are found at Singtali in the Ganga valley, in Satpuli-Lansdowne area, and at Dugadda, south-west of Lansdowne. However, KALIA (1974) discovered fusulinid, algal and bryozoan fossils from oolitic, shell limestone occurring near Dugadda. On this basis she suggested an Upper Permian age for these rocks.

VALDIYA (1975) on KALIA's fossil evidence suggested that the whole of the Tal is of Permian age and that the underlying Krol and Blaini are of much older age than hitherto accepted.

A systematic sampling was done of the limestone band exposed at Singtali. The samples were collected from the bed exposed on the right bank of the Ganga on the Rishikesh-Devprayag motor road, near the suspension bridge, NNE of the Singtali village. Study of these samples by the authors has revealed the presence of a rich algal assemblage and other associated microfossils in this limestone. The assemblage of the microfossils is suggestive of Permian time.

Since the discovery of Permian fossils from this litho-unit has a great bearing on the structure and tectonics of the Garhwal Himalaya, a systematic study of the fossils collected from these beds is being presented in this paper.

GEOLOGICAL SET UP

The oolitic shell limestone and associated rocks have been named as 'Singtali Formation' by the authors. It occurs as a linear belt near the Singtali village, and comprises shelly, often sandy, oolitic limestone, quartzite and shales. On the basis of fossil finds and some other field evidences the authors have suggested that the Singtali Formation be included as part of the Bijni Nappe of AUDEN and not a part of his Tal Formation.

The revised lithostratigraphic succession in the Bijni Nappe, as suggested by the authors and exposed in the Singtali area, is given in Table-1.

Table-1

Formation	Lithology		Age
Singtali ..	Grey compact shale	35.0 m	Permian
	Quartzite	6.0 m	
	Oolitic limestone	1.0 m	
	Quartzite	8.0 m	
	Oolitic limestone	25.0 m	
	Thinly bedded quartzite	1.5 m	
Bijni ..	Quartzite & phyllite		Devonian to Upper Carboniferous

A comparative statement showing the lithotectonic set up of the Garhwal Syncline established by auden (1937), RAVI SHANKER AND GANESHAN (1973) and the one suggested by the authors is given in Table-2.

SYSTEMATIC DESCRIPTION

In the present work the classification proposed by PAPENFUSS (1955) and modified by JOHNSON (1962) has been followed for taxonomic attribution.

Phylum—RHODOPHYCOPHYTA

Class—RHODOPHYCEAE

Genus—GYMNOCODIUM Pia, 1920

Gymnocodium bellerophontis (Rothpletz) Pia, 1920 (Pl. 1, Fig. 1)

The present material closely resembles *G. bellerophontis* (Rothpletz) and is the most widespread Gymnocodiacean in the flora. The specimens are mostly fragmented and the

Table 2—Lithotectonic set-up of the Garhwal Syncline

Auden (1937)		Ravi Shanker and Ganeshan (1973)			Present Authors
	Chandpur (metamorphosed)	AMRI UNIT	Schistose phyllites with Lansdowne Granite	AMRI NAPPE	Amri phyllite with Lansdowne Granite
	—Thrust—		—Amri Thrust—		—Amri Thrust—
	Nagthat) Little Chand-) metamor- pur) phosed	UPPER BIJNI UNIT	Purple, green, white quartzite with subordinate green and grey slate.		Bijni quartzite, shale, slate. boulder slate and phyllite, etc.
		—Bijni Thrust—			
GARHWAL NAPPE	Boulder bed, slate and limestone of uncertain stratigraphic horizon occur in one outlier below metamorphosed Chandpurs.	LOWER BIJNI UNIT	Sandy limestone, gritty quartzite, Boulder Slate, quartzite and phyllite.		
	—Garhwal Thrust—		—Garhwal Thrust—		
	Nummulitics		Subathu Formation		
	Upper Tal limestone and grit.		Upper Tal limestone member.	SINGTALI FORMATION	Grey compact shale, quartzite, oolitic limestone, quartzite, oolitic limestone, thinly bedded quartzite
				—Garhwal Thrust—	
					?Subathu Formation.
	Upper Tal quartzite.		Upper Tal quartzite member.		Upper Tal quartzite
			– – Disconformity– –		
KROL	Lower Tal shale Krol Series	KROL	Lower Tal Formation Krol Formation	KROL	Lower Tal Formation Krol Formation
NAPPE	Infra Krol) Blaini stage) Series Blaini Stage Jaunsar Series	NAPPE	Infra Krol Formation Blaini Formation Pre-Blaini Formation	NAPPE	Infra Krol Formation Blaini Formation Pre-Blaini Formation
—Krol Thrust—		—Krol Thrust—		—Krol Thrust—	
AUTOCHTHONOUS		SIWALIKS/NUMMULITICS/SIMLA SLATES			

longest fragment is about 3.5 mm long. However, as mentioned by JOHNSON (1962), the thallus may be as long as 19 mm. The dimensional data of the present material is as under:

Length of fragments	2.75-3.5 mm
Outer diameter of the fragments (average)	0.856 mm

Diameter of outer perforation (average)	.. ..	0.60 mm
Thickness of calcareous wall (average)	.. ..	0.128 mm
Diameter of pores on the outer surface (average)	.. ..	0.064 mm

Remarks—The species has so far been reported from the Upper Permian of Iraq (ELLIOTT, 1955), Italy (ACCORDI, 1956) and India (RAO & VARMA, 1953) and a similar age can be assigned to the beds containing them in the Garhwal Himalaya.

Gymnocodium cf. **nodosum** Ogilvie-Gordon, 1927 (Pl. 7, Figs. 2, 3)

The species is represented by a few well preserved segments. The present material satisfactorily compares with the type in shape, nature and dimensions of the thallus and in the tube characteristics. It may be mentioned that so far there has been no information on the position, shape, and size of sporangia in the earlier descriptions of the species; but sporangia are quite well preserved in the present specimens and these are oval in cross-section and cortical to sub-cortical in position.

The dimensional data of the present specimen is as under:

Maximum length of fragments	.. .. ..	3.210 mm
Diameter of broadest fragment	.. .. ..	0.642 mm
Thickness of calcareous wall (average)	.. .. ..	0.070 mm
Diameter of pores (average)	.. .. ..	0.060-0.085 mm
Size of the sporangia	.. ..	0.064×0.053 mm

Remarks—The species had till recently been reported only from the Upper Permian of northern Italy (ACCORDI, 1956).

Genus—**Permocalculus** Elliott, 1955

Permocalculus forcepianus (Johnson) Elliott, 1955 (Pl. 1, Fig. 4)

1951 **Gymnocodium forcepianus** Johnson, p. 28, pl. 9, figs. 3-9.

1955 **Permocalculus forcepianus** (Johnson) Elliott p. 86-87, pl. 2, fig. 3.

The present specimen closely corresponds with the morphology, growth habits and dimensions of the type described by JOHNSON (1951) from the Permian of the Apache Mountains, Texas.

The dimensional data of the present specimens and of the type are given below:

Species	Segment		Wall Thickness	Pore Diameter	Sporangia		
	Length	Diameter			Shape	Position	Size
P. forcepianus (Johnson) Elliott	2.6-5.9 mm	0.6-2.6 mm	160-660μ	26-40 μ	Ovoid	Cortical	130-205μ
P. forcepianus (present specimens)	..	1.498-1.7 mm	428-535 μ	28-63μ	Spherical to ovoid.	Cortical	128-140μ

Remarks—The species was originally reported from the Permian of Texas (JOHNSON, 1951).

Family—SOLENOPORACEAE

Genus—**Parachaetetes** Deninger, 1906

Parachaetetes sp. (Pl. 1, Fig. 5)

The genus is represented by a few ill-preserved fragments. The thallus consisting of a regular tissue with strong cross-partitions is clearly seen.

Remarks—In view of the poor preservation of the material specific identification was not attempted.

Phylum—CHLOROPHYCOPHYTA

Family—DASYCLADACEAE

Genus—**Anatolipora** Konishi, 1956

Anatolipora singtaliensis sp. nov. (Pl. 1, Fig. 6)

Diagnosis—Very small, club-shaped thalli, gently tapering towards base; central stem thin, fairly thick calcified wall; relatively small number of undivided clavate branches from each whorl, branches inclined to central stem; sporangia developed within the central stem.

Description—Thallus club-shaped, gently increasing in diameter, circular in cross section, 358 μ to 428 μ thick, and a thick well calcified cortical layer. The primary branches are inclined to the central stem and are unbranched. There are 22 to 29 branches in a whorl. The branches are club-shaped with rather flattened outer ends and these gently increase in size from the stem to about twice the original diameter at the periphery.

Etimology—After the village of Singtali in Garhwal Himalaya from where the samples were collected.

Remarks—While the present species closely resembles the genotype. *A. carbonica* Konishi (1956) in general morphological features, it appears to be a more evolved representative of the genus with better organisation of its whorls and branches. The branches are more stout than in *A. carbonica* and are larger in number. The whorls are more closely spaced with greater number of laterals per whorl than in *A. carbonica*. The dimensional data of the genotype and those of the present species are as under:

Species	Outer Diameter	Diameter of central stem	Diameter of branches at periphery	Distance between branches	No. of branches per whorl	Locality and horizon
A. carbonica Konishi	350-510μ	150-230μ	20-50μ	25-35μ	20-25	Upper Mississippian and Lower Permian of Japan
A. singtaliensis sp. nov.	358-428μ	256-265μ	upto 64μ	21μ	22-29	Singtali Formation, Garhwal Himalaya

The genotype was described from Kaksako Formation (Upper Mississippian) of southern Kyushu (KONISHI, 1956) and the same was later reported from the Permian of Japan by ENDO (JOHNSON, 1962).

Genus—**Anthracoporella** Pia, 1920

Anthracoporella sp. (Pl. 1, Fig. 7)

Description—The thallus is cylindrical with a median narrow, central stem. The primary branches are short and nearly cylindrical but thicken slightly outward. The secondary branches are in tufts of two. Sporangia not observed and they probably occurred in the central stem. The dimensional data of the present material are given below:

Thallus		Central stem	Primary branches	Secondary branches
Shape	Diameter	Diameter	Diameter	Diameter
Circular in cross section	342-385 μ	128-160 μ	21.4 μ	16 μ

Remarks—The present material closely resembles *A. spectabilis* PIA (1920) in morphological details but apparently is a much smaller form. While the genus probably originated in Middle Pennsylvanian, the only Pennsylvanian species *A. spectabilis* continues through Permian as well. The other three reported species are from the Permian.

Genus—**Clavaphysoporella** Endo, 1958

Clavaphysoporella elegantannulata (Endo & Kanuna) Endo, 1961 (Pl. 1, Fig. 8)

The present material closely resembles the type described from the Permian of Japan. The dimensional data of the present material along with that of the type are given below:

Species	Diameter			Locality
	Outer	Central Stem	Branch	
C. elegantannulata (Endo & Kanuna).	730-936 μ	325-468 μ	91-130 μ	Permian of Japan.
C. elegantannulata (Endo & Kanuna)	856 μ	428 μ	127 μ	Permian of Garhwal Himalaya

Remarks—The species is so far reported only from the Permian strata.

Genus—**Eogoniolina** Endo, 1953

Eogoniolina cf. *E. undulata* Endo, 1957 (Pl. 1, Fig. 11; Pl. 2, Fig. 14)

1957 **Eogoniolina undulata** Endo, p. 284, pl. 37, Figs. 6-7

The present material closely resembles *E. undulata* Endo. The thallus is club-shaped and is circular or slightly oval in cross-section. The long cylindrical central stem is rather slender in the basal portion and expands gradually toward the top into a spherical or egg-shaped mass. The branches which grow nearly perpendicular to the central stem, have the shape of gently expanding cones with rounded ends, and the greatest diameter is near the outer end.

The dimensional data of the present material as well as of the type are given below:

Morphocharacters		*E. undulata* Endo, 1957 p. 284, pl. 37, figs. 6, 7.	*E.* cf. *E. undulata* Endo
Outer diameter	near top	1.053-1.512 mm	1.070 mm
Central stem diameter	near top	675-743 μ	0.470 mm
	lower end		0.428 mm
Branch diameter	top	108 μ	128 μ
	lower end		108 μ
Thickness of calc. wall	top		428 μ
	lower end		256 μ
Branches per whorl		20+	..
		Upper Permian of Japan	Garhwal Himalaya

Genus—**Epimastopora** Pia, 1922

Epimastopora sp. (Pl. 2, Fig. 15)

Description—Thallus large, fragmented, probably cylindrical with a thick central stem. Numerous long primary branches probably arranged in fairly regular, closely spaced whorls; successive whorls alternate in position so that the branches appear to be arranged in spiralled rows round the primary stem. Diameter of branches ranging from 107 to 149 μ spaced at distances of 21 to 42 μ apart.

Remarks—The present material resembles *E. lateinterporosa* Endo (1961) described from the Permian of Japan in morphology and in dimension of branches. However, no specific identification was attempted in view of the fragmentary nature of the present material.

Genus—**Gyproporella** Gümbel 1872 emend. Beneches, 1876

Gyroporella symetrica Johnson, 1951 (Pl. 2, Fig. 21)

The present form is closely allied to the type described by Johnson (1951) from the Middle Permian of Apache Mountains, Texas.

The thallus is long, club-shaped and circular to oval in cross-section. The central stem is also club-shaped and is relatively wide in proportion to the entire thallus. The primary branches are of the shape of drum sticks (i.e. a slender stem with a spherical expansion at the end) and are arranged in closely spaced whorls. Sporangia are spherical, developed at the ends of some of the primary branches in the upper part of the thallus.

The dimensional data of the type is given below together with those of the present material:

Species	Thickness	Diameter		Locality & Horizon
	Calc. stalk	stem	branches	
G. symetrica Johnson, 1951, p. 25, pl. 8, fig. 7, pl. 10, figs. 1-5.	220-480 μ	350-1700 μ	66-123μ	Middle Permian of Apaches Mts., Texas
G. symetrica Johnson	214-428 μ	470-535 μ	64 μ	Garhwal Himalaya

Genus—**Mizzia** Schubert, 1907 emend. Rezak, 1959

Mizzia velebitana Schubert, 1908 (Pl. 1, Fig. 9)

The present material closely resembles *M. velebitana* Schubert (1908) in morphology and dimensions. The individual segments are oval in cross-section with an outer diameter of 1712μ × 1391μ. Inner diameter of the segment is 1177 μ × 963 μ. Simple, unbranched primary branches thicken first gradually and then abruptly toward the exterior. The branches are 42 μ to 98 μ in thickness.

Remarks—This species which has almost world wide distribution towards the close of the Permian has been accepted as an index fossil of Upper Permian. Distribution, range and associated fauna and flora have been discussed in great detail by Dorr and Johnson (1942). The occurrence of this species in the Permian of Garhwal Himalaya is of interest in this context.

Genus—**Oligoporella** Pia, 1912

Oligoporella nipponica Endo, 1956 (Pl. 1, Fig. 10)

The present material closely resembles *O. nipponica* described by Endo (1956) from the Permian of Kwanto and Kitakami mountains of Japan. The thallus is cylindrical having a cylindrical central stem that is moderately thick. The primary branches occur in tufts of three; these bear tufts of short, slender tertiary branches.

The dimensional data of the type as well as of the present material are given below:

Species	Diameter			Thickness calc. wall	Locality and horizon
	Outer	Inner	Primary branch		
O. nipponica Endo, 1956	1.29-2.16 mm	0.81-1.42 mm	0.14-0.24 mm		Permian of Japan
O. nipponica Endo.	1.633-1.836 mm	1.02 mm	0.214 mm	0.321 mm	Garhwal Himalaya

Remarks—The species was originally described from the Permian of Japan.

Genus—**Pseudoepimastopora** Endo, 1960

Pseudoepimastopora krishnaswamyi sp. nov. (Pl. 2, Fig. 13)

Diagnosis—Thallus relatively short, elliptical with circular cross-section. The unbranched primary branches are arranged perpendicularly to both inner and outer surfaces and develop ball-shaped expansions near the outer end.

Comparison—Only two species had earlier been assigned to this genus, viz. *P. japonica* (Endo) and *P. pertunda* Endo, the present species compares well with the former but differs from it by having a much thinner central stem in comparison to the total diameter of the thallus. The calcareous wall in the present material is thicker than that in *P. pertunda* Endo.

The dimensional data of *P. krishnaswamyi* sp. nov. together with those of the known species of *Pseudoepimastopora* are given below:

Species	Diameter			Locality & horizon
	Central stem	Outer	Primary branches	
P. japonica (Endo), Endo, 1951, p. 124-125, pl. 11, figs. 1-2; Endo, 1960, p. 269, pl. 44, fig. 1.			95 μ	Lower Permian of Japan
P. pertunda Endo, 1960, p. 268-269, pl. 44, figs. 2-6.	1.080-1.890 mm.		149-229 μ	Middle Permian of Japan
P. krishnaswamyi sp. nov. ..	0.428-0.642 mm	0.963-1.177 mm	171-192 μ	Garhwal Himalaya

Etimology—After Shri V. S. Krishnaswamy, Dy. Director General, Geological Survey of India, who has kindly taken great interest in the present work.

Family—CODIACEAE

Genus—**Anchicodium** Johnson, 1946

Anchicodium sp. (Pl. 2, Fig. 20)

Description—Thallus crustose from which straight or nearly straight cylindrical stems develop. These are composed of a spongy mass of rounded threads which are poorly organised in the central portion and toward the outer surface the threads tend to become parallel. These threads end in tufts of fine branches that are perpendicular to the outer surface. The dimensional data of the present material are given below:

Diameter		Thickness of thallus	Length of thallus
Medullary tubes	Branches on the outer surface		
74 μ	32-42 μ	214-642 μ	2.033 mm

Remarks—Due to the imperfect nature of preservation, specific identification was not attempted.

Genus—**Hikorocodium** Endo, 1951

Hikorocodium transversum Endo, 1957 (Pl. 2, Figs. 16, 17)

The present material closely resembles *H. transversum* Endo from the Upper Permian of Honsu, Japan. The thalli are cylindrical, rather undulating with rounded ends. Thallus is composed of a poorly organised, pith-like central stem and branched, anastomosing, tubular pores in the peripheral part. The pores are given off from the central stem at about right angles or slightly ascending. The radiating pores are usually undulating and more or less distinctly dichotomously branched. The pores usually run with the same width from the central stem to near the surface of the thallus where they end bluntly with rounded terminations.

The dimensional data of the present material are as under:

Segment			Central stem		Pores	
Length	Width	Shape	Size (Dia.)	Nature	Size (Dia.)	Nature of branching
1.712 mm	1.07 mm	Compressed oval in cross-section	642 μ	Circular to oval in cross-section	107 μ	Dichotomous

Remarks—The taxonomic position of this genus has been debated in recent years. ENDO's original description and illustrations are clearly suggestive of a rather poorly preserved green alga (ENDO, 1952, 1957). However, *H. fertilis* Endo described from the Jurassic of Shikoku, Japan (ENDO, 1961) really suggested stromatoporoids and subsequently the genus was tentatively described as of uncertain affinities (JOHNSON, 1964.) However, the present material is clearly suggestive of codiacean algae.

Genus—**Ortonella** Garwood, 1914

Ortonella gracilis Johnson, 1951 (Pl. 1, Fig. 12)

The present material is closely allied to *O. gracilis* Johnson. The thallus forms small, rounded, nodular masses 856 μ×749 μ across. These masses consist of a series of fine remifying tubes, 21 μ – 26 μ in diameter, which radiate from a centre. The tubes are straight or slightly undulating and are completely separated, individual tubes proceeding with almost uniform diameter from centre up to the outer end. The tubes branch dichotomously with an angle of divergence of as much as 30° and these gradually become parallel towards the outer surface.

The dimensional data of the present material as well as those of the type are given below:

Species	Tube diameter	Angle of divergence	Horizon and locality
O. gracilis Johnson, 1951, p. 29	22-26 μ ..	35°—40°	Permian of Texas
O. gracilis Johnson	21-26 μ ..	30° ..	Garhwal Himalaya

Remarks—The species is known from the Permian of Texas.

Genus—**Succodium** Konishi, 1954

Succodium hikorocoides Endo, 1957 (Pl. 2, Figs. 18, 19)

The present material closely resembles *S. hikorocoides* Endo, described from the Upper Permian of Japan. The branching thallus consists of articulated segments. Each segment consists of (1) a feebly calcified medulla of longitudinal, ramified filaments, (2) a strongly calcified subcortical part of irregularly interwoven utricles, and (3) a thin outer cortical layer. Gametangia-like expansions are disposed along the boundary of sub-cortical and cortical parts.

The dimensional data of the type and of the present material are as follows:

Species	Segment			Inner Dia.	Dia. of cortical utricles	Sporangia Dia.	Locality and horizon
	Shape	Length	Dia.				
Shikorocoides Endo, 1957		55 mm	1.728 mm	0.486 mm	..	..	Upper Permian of Japan
S. hikorocoides	elliptical	3.424 mm	1.498 mm	0.856 mm	32 μ	342 μ	Garhwal Himalaya

Remarks—The present material clearly shows the nature, position and size of the sporangia.

Repository—All the figured slides are deposited in the Palaeontology Division, Northern Region, Geological Survey of India, Lucknow.

REMARKS ON AGE

The assemblage of algal fossil remains recovered from the Singtali Formation includes seventeen species belonging to sixteen genera. Out of these the specific identification of the genus *Parachaetetes* could not be carried out due to the poor preservation resulting in ambiguity in specific characters. The genus is a long ranging alga from Ordovician to Palaeocene. However, it is significant to note that, reportedly, this genus also occurs in the Krol Formation of Mussoorie area (Mittal & Chaturvedi, 1972, Pl. 51, Fig. 2). Other algal species, except *Anthracoporella* sp., under reference, are restricted to the Permian horizon. Amongst them, a number of forms, viz. *Gymnocodium bellerophontis* (Rothpletz), *G. nodosum* Ogilvie-Gordon, *Eogoniolina* cf. *E. undulata* Endo, *Hikorocodium transversum* Endo, *Succodium hikorocoides* Endo and *Mizzia velebitana* (Schubert) are restricted to the Upper Permian period.

It may be noted here that Dorr and Johnson (1942), based upon their studies of the world-wide distribution of the algal species *Mizzia velebitana*, concluded that this form should be regarded as the index fossil for the Upper Permian.

Some of the associated microfossils from the Singtali Formation, presently under study, included two bryozoan genera *Rhombopora* and *Rhabdomeson*, which again point to an Upper Palaeozoic affinity.

DISCUSSION

MEDILCOTT (1964) first suggested the status of Tal Formation to a group of rocks that included shell limestone (Singtali Formation of the authors) on top in the Tal valley in south-western Pauri Garhwal. In years to follow the shell limestone continued to be considered as Tals and as such the topmost unit of Krol Nappe in the Garhwal Syncline.

The Tals were viewed to be of age between Triassic and Cretaceous by most of the geologists. However, the occurrence of Permian algae in the oolitic shell limestone, a unit of Tals of AUDEN (1937) in Singtali area poses problem for its stratigraphic position relating to Tals and also its bearing on structure and tectonics of the Garhwal Syncline as a whole. KALIA (1974), on finding indisputable Permian fossils from the impure oolitic shell limestone exposed in Dugadda area, concluded '......that the supposed equivalence of these beds to that of the type Tal Formation is erroneous; or the Tal Formation itself is Upper Palaeozoic......'. Similarly, VALDIYA (1975), on the basis of his studies and other palaeontological evidences, implied that the whole of the Mesozoic group is missing in the Lesser Himalaya. He assigned the Tals a Permian age.

The oolitic shell bearing impure limestone and interbedded quartzite in the Singtali area were included by previous workers in the Tals as the upper-most member. But the find of algal and other microfossil assemblage in the shell limestone of Singtali Formation is suggestive of Permian times and contrary to the view of previous workers. If the age of the Tal Formation, excluding the Singtali Formation, is between Triassic and Cretaceous, these Permian beds (Singtali Formation) cannot be a part of the same. The rocks overlying the Singtali Formation are of the Lower Bijni unit of RAVI SHANKER AND GANESHAN (1973), to which they have assigned Upper Carboniferous age separated from their Upper Bijni unit by the Bijni Thrust.

The occurrence of Permian beds over the Tals (Trias-Cretaceous) is itself suggestive of an abnormal superposition. The normal succession of the Krol group of rocks from Jaunsar-Blaini-Krol-Tal contradicts the possibility of an inverted sequence of rocks. There can only be one solution, i.e. the relation between the Singtali and the Tals is of tectonic nature. More precisely the Singtali Formation and the Tal Formation belong to two different tectonic units.

RAVI SHANKER AND GANESHAN (1973, Fig. 1) and RUPKE (1974) have indicated the presence of Eocene beds over the Tals (overlying Singtali limestone) on the basis of which they have marked the position of Garhwal Thrust in this area. The authors could not find any fossils in the olive green shale occuring above the Singtali limestone and below the Bijni quartzite. However, at hin bed of shale having disc shaped bodies ranging in size from a fraction of a mm to 2 mm occurs *below* the Singtali Formation. No fossils have so far been discovered from this bed, but the authors would like to suggest that this may possibly represent remenant of Eocene rocks, as such disc like bodies have been reported from a horizon in the undoubted Subathu Formation of Dharampur area, H.P. On the basis of the occurrence of this doubtful Eocene strata underlying the Singtali Formation and discovery of Permian fossils from the latter, the authors have put forward the suggestion that the Garhwal Thrust probably passes below the Singtali Formation and that the Singtali Formation (a part of Tal Formation of earlier workers) should be included into the Lower Bijni unit of RAVI SHANKER AND GANESHAN (1973).

Although the discovery of Permian fossils from the Singtali Formation implied the demarcation of the Tal Formation afresh, the authors do not however, agree with VALDIYA (1975) that the whole of Mesozoic succession is missing from the Lesser Himalaya. In the

GEOLOGICAL MAP OF GARHWAL SYNCLINE

(AFTER RAVI SHANKAR AND GANESHAN 1973, & RUPKE 1974)

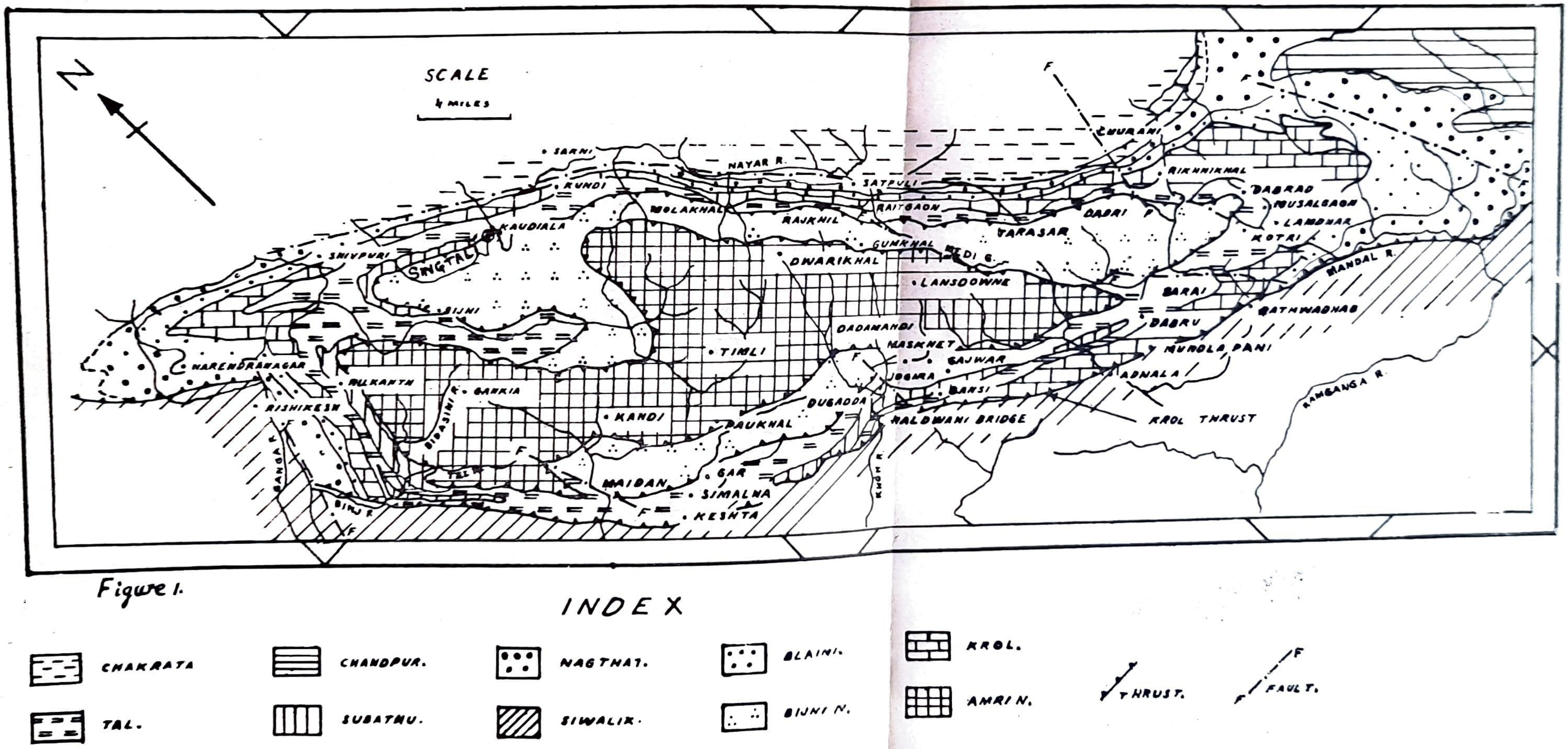

Figure 1.

opinion of the authors, this discovery has only necessitated restudy of the Tals of the earlier workers so that the extent of the Permian beds and their relation to the *remaining* part of the Tal Formation may be properly demarcated in this part of the Himalaya. VALDIYA (1975) has further commented on the study of the microfloral and similar remains discovered from the Blaini, Infra-Krol and other formations. Surprisingly, he has not mentioned the fossil finds from the Blaini and associated rocks that came to light recently, viz. palynomorphs by SHRIVASTAVA AND VENKATARAMAN (1974) including such short range forms as *Densosporites* sp., *Maranhites* sp., *Reticulatisporites* sp., and *Tetraporina* sp. PRASAD AND BHATIA (1975) reported algae, shell fragments, dinoflagellates, and silicified moulds of foraminifera like *Proteonina*, *Saccammina*, and *Ammovertella*, all suggestive of Lower to Upper Carboniferous age, and the bryozoans from the Simla Formation and Chandpur Formation indicative of Ordovician age (AGARWAL, 1974; SHUKLA, SURYA NARAIN & SRIVASTAVA, 1974). The implication of these fossil finds may be debatable but the presence of the fossils from the associated rocks cannot be denied. This discrepancy of the fossil finds, as suggested by VALDIYA (1975) further confirms the view of the authors that the geology of the Lesser Himalaya needs rethinking.

GANESHAN (1971, 1972) has divided the boulder slate succession of Dugadda area as sandy limestone, gritty quartzite, and boulder slate. He discovered fenestellids from the Boulder Slate indicating Middle to Upper Carboniferous age. TEWARI (1974) has reported scolecodonts from the sandy limestone horizon of GANESHAN (1973) suggestive of Devonian age. He suggested the stratigraphic succession worked out by the earlier workers to be in reverse order. The discovery of the Permian fossils from the Singtali beds by the authors (Lower Bijni tectonic unit of RAVI SHANKER AND GANESHAN, 1973) further confirms the postulation of TEWARI (1974) regarding the overturned succession in this unit.

VALDIYA (1975), while reconstituting the geology and structure of Garhwal Himalaya has included the Boulder Slate of RAVI SHANKER AND GANESHAN (1973) in his Jogira member of Tal Formation. He has completely overlooked the presence of Nummulitics between the Tals and the Lower Bijni Unit of RAVI SHANKER AND GANESHAN (1973). The presense of Nummulitics contradicts his postulation of including the Krol and the Lower Bijni Nappes in one. The Tals and Bijni are entirely different tectonic units separated from each other by the Garhwal Thrust and as such, cannot be included in one Formation as suggested by VALDIYA (1975).

The fossil locality of KALIA (1974) near Dogadda area, probably forms the continuation of the Singtali Formation of the authors and not Bansi member of Tal.

CONCLUSIONS

1. It is evident from the microfossil studies that the age of the Singtali Formation, 'shell limestone' of AUDEN (1937) and 'limestone member' of RAVI SHANKER (1971), is Permian.

2. Unless the Tals are stratigraphically well defined, it is difficult to conclude that the whole of Tal Formation is of Permian age.

3. The Garhwal Thrust does not pass above the oolitic limestone horizon of Tal but the latter, possibly, is a part of the lower Bijni Nappe of RAVI SHANKER AND GANESHAN (1973).

4. The succession of the Lower Bijni is overturned.

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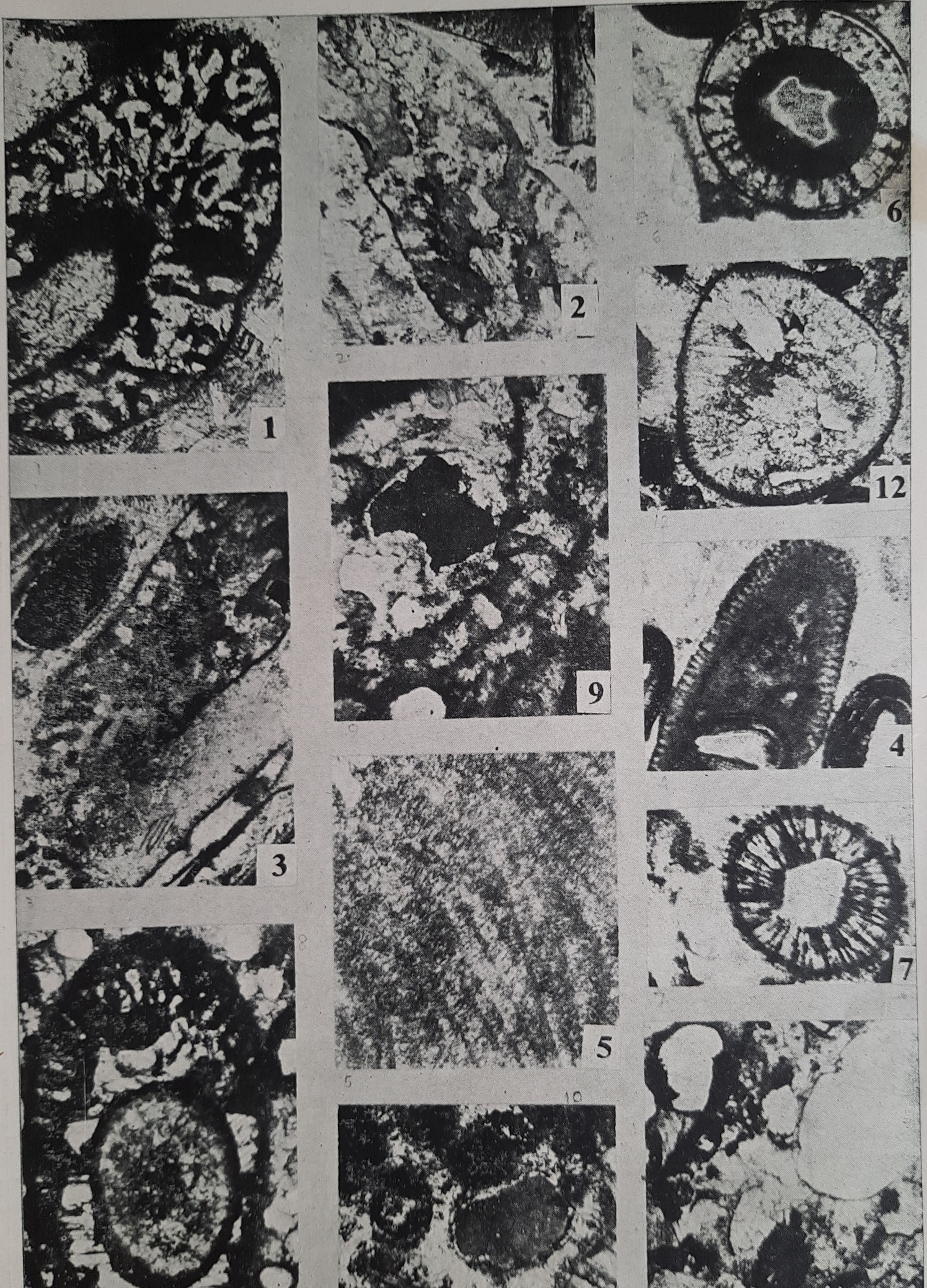
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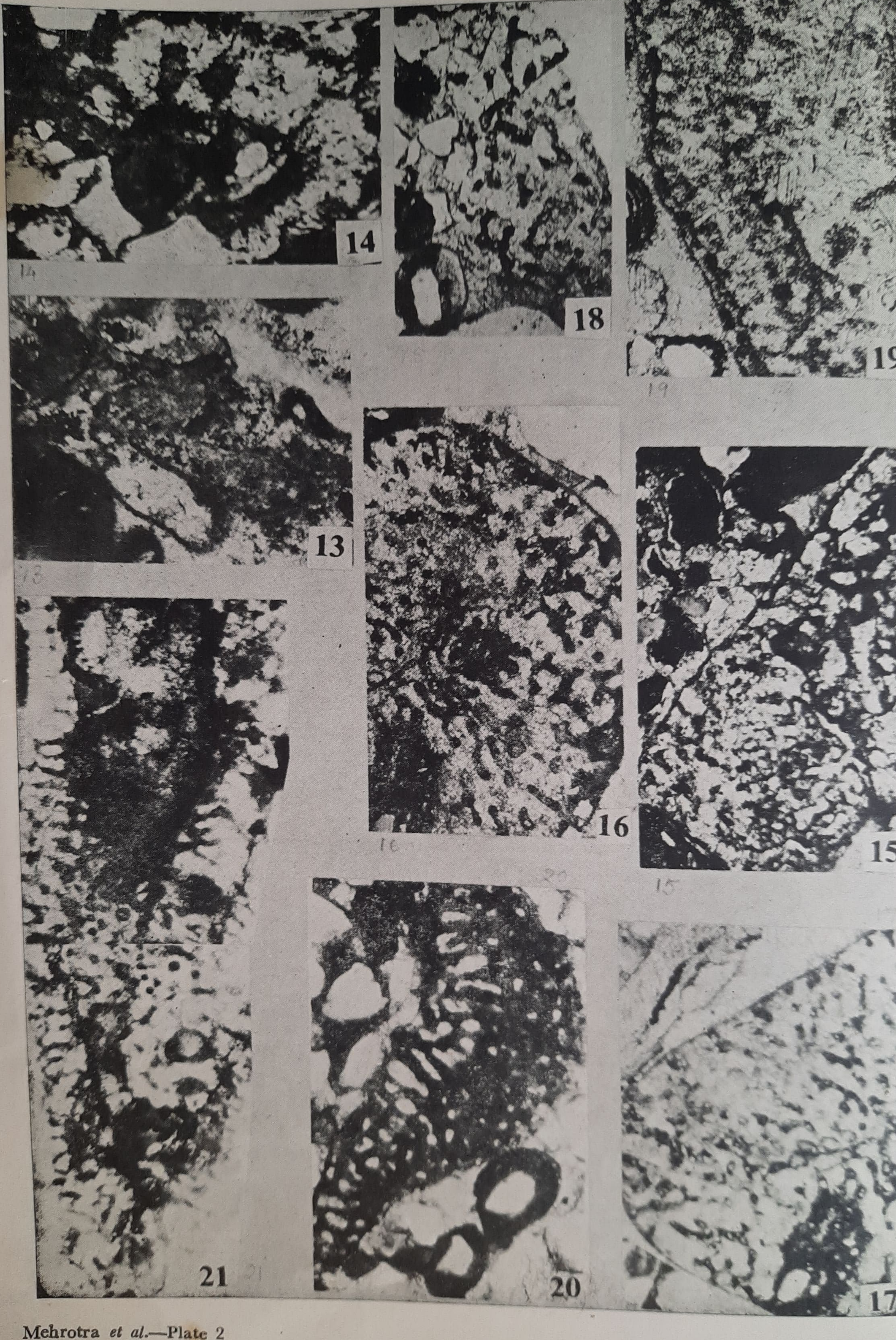

Mehrotra *et al.*—Plate 2

VALDIYA, K. S. (1975). Lithology and age of the Tal Formation in Garhwal, and implication on stratigraphic scheme of Krol Belt in Kumaun Himalaya *Jour. geol. Soc. India.* **16**(2): 119-134.

EXPLANATION OF PLATES

PLATE—1

1—*Gymnocodium bellerophontis* (ROTHPLETZ). Oblique section of a fragment. ×40. 2, 3—*Gymnocodium* cf. *nodosum* OGILVIE-GORDON. Longitudinal section. ×40. 4—*Permocalculus forcepianus* (JOHNSON) Longitudinal section of fragments. ×20. 5—*Parachaetetes* sp. Longitudinal section showing nature of tissue. ×20. 6—*Anatolipora singtaliensis*, holotype, n. sp., Transverse section. ×40. 7—*Anthrocoporella* sp. Transverse section. ×40. 8—*Clavaphysoporella elegantannulata* (ENDO). Oblique-longitudinal section. ×40. 9—*Mizzia velebitana* (SCHUBERT), Oblique section. ×20. 10—*Oligoporella nipponica* ENDO, Oblique section. ×20. 11—*Eogoniolina* cf. *E. undulata* ENDO. Oblique-longitudinal section. ×20. 12—*Ortonella gracilis* JOHNSON, Transverse section. ×40.

PLATE—2

13—*Pseudoepimastopora krishnaswamyi* n. sp. Oblique-longitudinal section. ×20. 14—*Eogoniolina* cf. *E. undulata* ENDO. Transverse section. ×20. 15—*Epimastopora* sp. Longitudinal section of a fragment. ×20; 16, 17—*Hikorocodium transversum* ENDO, Oblique section. ×40; 18, 19—*Succodium hikorocoides* ENDO, Oblique Section. ×20; 20—*Anchicodium* sp. Vertical section. ×40; 21—*Gyroporella symetrica* Johnson. Longitudinal section. ×20.