VENDOTAENIDS : EARLIEST MEGASCOPIC MULTICELLULAR ALGAE ON EARTH

V.C. TEWARI
Wadia Institute of Himalayan Geology, Dehra Dun-248 001, India.

ABSTRACT

The Vendotaenids are the oldest multicellular megascopic brown algae recorded in the early history of evolution of plant life on planet Earth. The morphological characteristics of Vendotaenids, its global distribution, genetic, biochemical, isotopic and palaeoecological aspects have been described. The Vendotaenids are quite significant in understanding the evolution of uni to multicellular algae on Earth. Possible occurrence of stromatolites and algae on Mars is also discussed.

INTRODUCTION

Vendotaenids are oldest known multicellular brown algae (plants) in the history of the Earth. Vendotaenian flora was first discovered by Gnilovskaya (1971) from Vendian rocks of the East European platform (≈650 Ma). Gnilovskaya (1988) in a monographic study established the morphological and anatomical characteristics of the macroscopic Vendian uni to tissue multicellularity. The peculiar tissue structure was also recognized by biochemical analysis of Vendotaenian algae. Vendotaenian algae was found very useful in biostratigraphic sub division of Vendian Podolia basin and in palaeoecological reconstructions.

Tewari (1988) discovered Vendotaenid algae from the Lower Krol Formation of Vendian age from the Himachal Lesser Himalaya of India. A new genus *Kroloataenia gnilovskayi* was established and subsequently the genus *Tyrasotaenia* and *Vendotaenia* have been recorded from Nainital syncline of the Kumaon Lesser Himalaya (Fig. 1 and Fig. 2). The Vendotaenids are also recorded from the Sinian System (Late Proterozoic) of China (Cao Ruiji and Zhao Wenjie, 1978). Though the Vendotaenid remains are quite abundant in late Vendian but its stratigraphic range may extend back to 1,800 Ma (Hofmann and Chen, 1981).

In the present paper the main morphological characteristics of Vendotaenian algae, its global distribution, genetic, biochemical, isotopic and palaeoenvironmental significance has been discussed.

GLOBAL DISTRIBUTION OF VENDOTAENIDS, MODE OF OCCURRENCE AND CHARACTERISTICS

Vendotaenids algae are most abundantly found on bedding planes as reddish brown or black ribbons, often fragmentary, unbranched and curvilinear, twisted or untwisted remains. The genera *Vendotaenia* is untwisted whereas *Tyrasotaenia* is characteristically twisted. However in genus *Krolotaenia* and type species *K. gnilovskayi* Tewari lateral branching has been observed frequently (figure 3/4; plate 1/4) but infrequent branching of a single ribbon into two parallel ribbons and untwisted nature is a characteristic feature of Lesser Himalayan Vendotaenids (Tewari, 1988, 1991, 1993a, b). The genus *Tyrasotaenia* differs from *Krolotaenia* by its

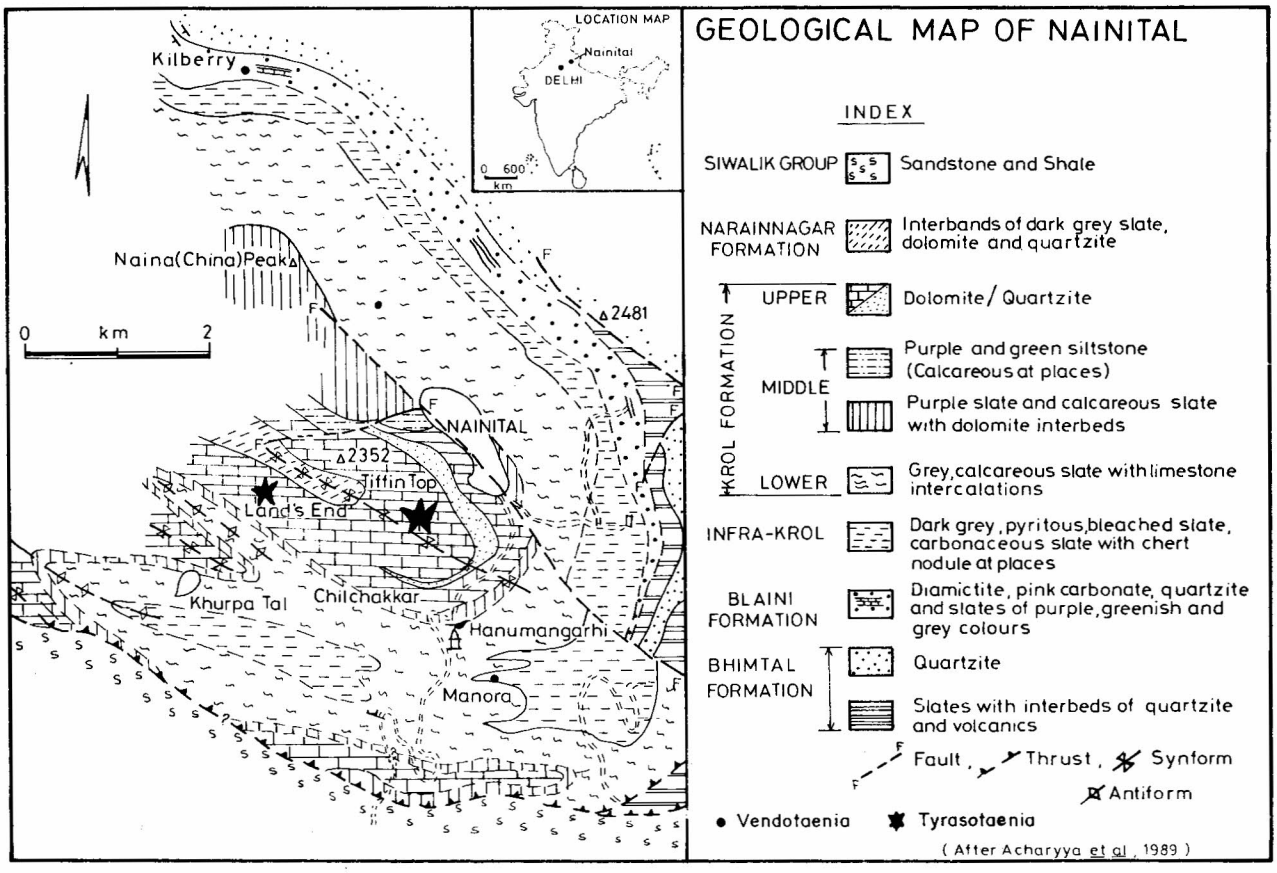

Fig. 1 Geological map of Nainital syncline after (Acharya *et al.*, 1989) showing Vendotaenid localities.

unbranched twisted and crumpled ribbons (Figure 3/1; plate 1/1). Narbonne and Hofmann (1987) described a new genus *Daltaenia mackenziensis* from the Little Dal Group, Mackenzia Mountains, Supergroup, North Western Canada. *D. mackenziensis* is characterised by unbranched ribbions, infrequent lateral branching, greater rigidity and their association with abundant *Chauria circularis*. There are various records of biota resembling Vendotaenid remains from different parts of the world but they lack in distinctive characteristics and their biological affinities are uncertain.

CLASSIFICATION AND SYNONYMS OF VENDOTAENIAN REMAINS

The monograph edited by Gnilovskaya (1988) contains the detailed supergeneric classification of Vendotaenides (Gnilovskaya, 1971) and Vendophyceae (Gnilovskaya, 1988). *Vendotaenia Gnilovskaya* is considered the oldest multicellular phaeophyte (Brown algae) or a rhodophyte (Red algae, see Gnilovskaya,1971). Hofmann (1922) regarded some carbonaceous megascopic ribbon shaped remains as algae (metaphyte) affinities of Neoproterozoic age. Schopf *et al.* (1973) described *Vendotaenia* as multicellular macroscopic benthic metaphytes. Vendophyceae has been further subdivided into three orders :

> VENDOTAENIALES, EOHOLYNIALES and EICHWALDIALES on the basis of laminar thallus organization. (Gnilovskaya and Kolasnikov, 1988)

SYNONYMS

Vendotaenia, Aataenia, Katnia, Laminarites, Proterotainia, Sinotaenia, Tyrasotaenia, Vindhyania and *Krolotaenia.*

EUKARYOTIC METAPHYTE AND METAZOAN EVOLUTION

The ultrastructure of the *Vendotaenia* shows

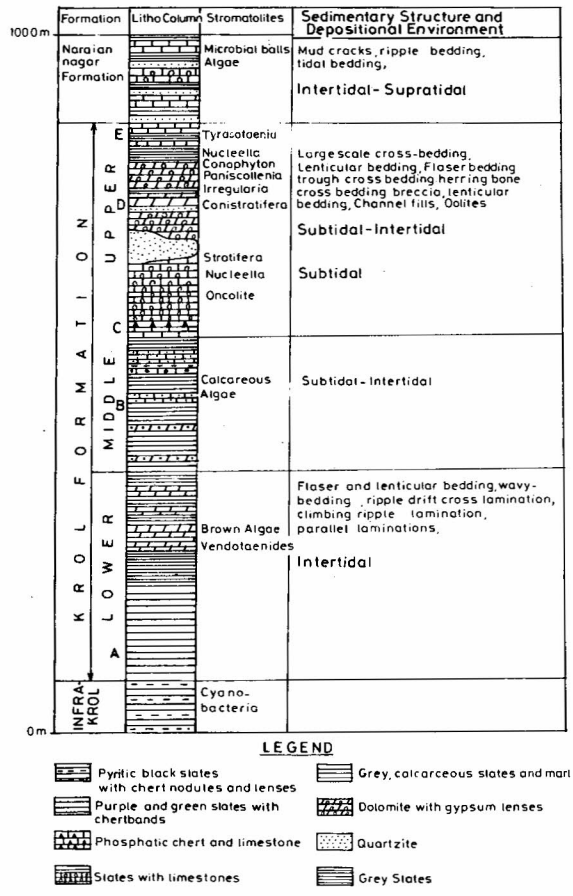

fig. 2 Lithocolumn of Krol Formation, Nainital syncline, Lesser Himalaya, India showing Vendotaenid algae, stromatolites and depositional environment.

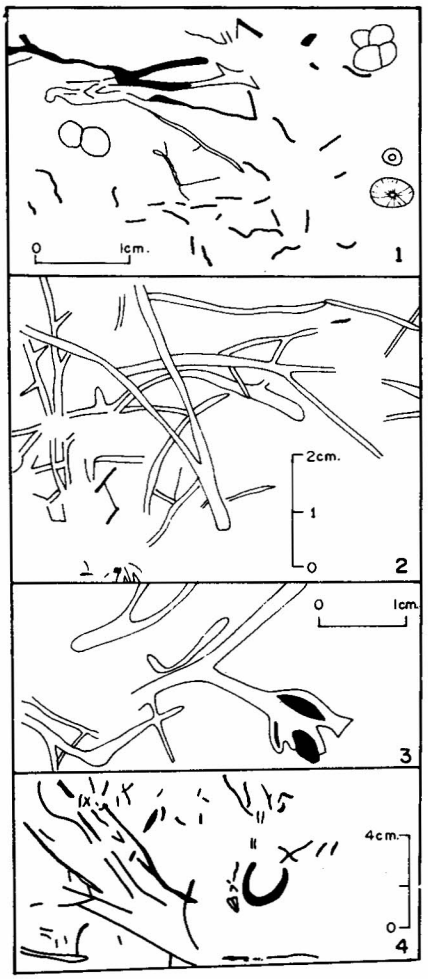

fig. 3 Diagramatic sketch of Vendotaenid from lesser Himalaya, India (1. *Tyrasotaenia*, 2. *Vendotaenia* sp. 3. *Vendotaenia antiqua*, 4. *Krolataenia gnilovskayi* Tewari)

a thin wall with fibrous texture and *Tyrasotaenia* has a smooth wall. *Vendotaenia* is a eukaryotic algae. According to Gnilovskaya (1988) among the plants Vendotaenians were the most ancient flora which acquired the tissue level of organisation. The development of a true tissue multicellularity organization of living matter is a peculiar feature of the Vendian stage. It may have occurred simutaneously both in plant (Metaphytes) and animals (Metazoans). Knoll (1966) is of the view that *Tyrasotaenia* may be eukaryotic but of animal origin.

It is interesting that Vendotaenid assemblage coincides with Ediacaran metazoan biozones in Canada (Narbonne and Hofmann, 1987) and Lesser Himalayan Krol belt carbonates (Tewari, 1991, 93a, b). This supports the simulatenous eukaryotic evolution of metaphytes and metazoans during Neoproterozoic or Vendian times. The genus *Tyrasotaenia* is found associated with *Beltanelliformis, Chuarids* and some possible Ediacaran biota (Figure 3/1; plate 1/1) in the Upper Krol Formation of the Nainital syncline. The other Ediacaran metazoans already discovered from these beds are *Charniodiscus* and *Pteridinium* (Tewari, 1993a, b, 1996a). Thus, *Tyrasotaenia* could be of eukaryotic animal affinity.

Gnilovskaya and Kolesnikov (1988) further reported longitudinal fibrous structure on thallus surface of *Vendotaenia antiqua*. This longitudinal fibrous pattern is represented by longitudinal cellular rows of the epidermal layers of the thallus. A new genus *Primaria* is also proposed by them.

BIOCHEMICAL, ORGANIC GEOCHEMICAL AND ISOTOPIC SIGNATURES FROM VENDOTAENIDS

The presence of common sugars, amino acids and lipids were recorded from *Vendotaenia* algae (Gnilovskaya and Kolesnikov, 1988). Vendotaenids are photosynthesizing plants and presence of porphyrins confirm its derivation from Cholorophyll. The biochemical elements of Vendian Vendotaenids is similar to the recent brown algae. The presence of cutin in Vendotaenids supports that this is a highly organised eukaryotic multicellular algae. Histochemical technique has analysed the cutin in cuticules. (Gnilovskaya and Kolesnikov, 1988).

Vendotaenid algae is found in Dengying Formation of China in association with filamentous cyanobacteria, calcieifed cyanobacteria, stromatolites and sphaeromorphic acritarchs (Cao Ruiji and Zhao Wenjie, 1978). Fan Pu *et al.*, (1992) have identified diverse biomarkers (aromatic hydrocarbons) present in Dengying Formation of Sinian age. These biomarkers are isolated from stromatolitic dolostones, cyanobacteria, algae and bacteria. The Krol Group of the Lesser Himalaya, India is correlated with Dengying Formation of China on the basis of similar occurrence of Neoproterozoic stromatolites, Vendotaenids, Ediacaran metazoans, cyanobacterial remains and acanthomorphic acritarchs (Tewari, 1993a; Tiwari and Knoll, 1995) The Infra Krol Cherts of the Lesser Himalaya contain abundant and diverse organic walled microfossils similar to Doushantuo Formation of China (Tiwari and Knoll, 1995). The Lower Krol Formation of the Lesser Himalaya contain Vendotaenid *Krolotaenia gnilovskayi* (Fig. 3/4; Plate ¼) *Vendotaenia antiqua* (fig. 3/3; Plate 1/3) whereas the Upper Krol Formation is characterised by the presence of *Tyrasotaenia* (Fig. 3/1; Plate 1/1) Tewari; 1988, 1993a).

CARBON AND OXYGEN ISOTOPIC GEOCHEMISTRY OF VENDOTAENIDS

The Krol carbonate rocks containing Vendotaenid algae, stromatolites, oncolites and ooids are microbial and their large scale deposition during Neoproterozoic time indicates a relative enhanced microbial buildup which preferentially fixed ^{12}C in the form of organic carbon (Corg.), this resulting ^{13}C enrichment in carbonate carbon. The shales containing Vendotaenid ribbons represents envelopes of anoxic bacteria in Himalaya, China and Iran. These shales show very low ^{13}C indicating bacterial blooms.

The Lower Krol Shows $\delta^{13}C$ value of +1% o(PDB) and rise in the Upper Krol depicting a $\delta^{13}C$ maximum of +6%o (PDB) (Tewari, 1991; 96a, Kumar and Tewari, 1995). The $\delta^{13}C$ org. value of the Krol Formation is -27.6%o. This is similar to the global trend of the marine carbonate carbon and organic carbon isotopic values of Neoproterozoic sea water. Schidlowski (1988) proposed that values in the range 26 + 7%o are broadly representative and convey "a remarkably consistent isotopic signal of autotrophic carbon fixatiion reflective of an extreme degree of evolutionary conservatism in the biochemistry of photoautotrophy. The carbon isotopic composition $\delta^{13}C$ per mil Vs PDB of stromatolitic carbonates and microbial balls of Nainital syncline (Fig. 2) varies from 2.70 to 4.3% o (PDB).

PALAEOECOLOGY OF VENDOTAENIDS

The eukaryotic algae abundantly diversified in open marine, coastal, tidal flat environment. Knoll (1982) suggested that while the eukaryotes occupied the Neoproterozoic planktonic realm, the prokaryotes occupied the benthonic realm where benthic microbial communities (BMC's) were dominant. The stromatolites developed on these microbial mats and formed large buildups in Upper Proterozoic time. The metaphytes and metazoans of Terminal Proterozoic continued to thrive on tidal flats in marine realm (Fig. 2)

The Vendotaenids bearing beds of the Krol Group of Lesser Himalaya are characterised by the

presence of sedimentary structures like wavy bedding, ripple bedding, rhythmtes, small scale cross bedding, flaser and lenticular bedding, climbing ripple laminations and parallel laminations (Figure 2). These structures indicate depositional environment in intertidal flat or near-shore shelf condition (Tewari, 1993b). Stromatolites are found in the Upper Krol Formation of the Nainital syncline and indicate a subtidal to intertidal depositional environment (Figure 2). The sedimentological evidences from the Dengying Formation of China also support development of hypersaline conditions during deposition of microbial carbonates which contain abundant carbonaceous macrofossils (Vendotaenids) and stromatolites. (Cao Ruiji and Zhao Wenjie, 1978).

EXTRATERRESTRIAL PALAEOEXOBIOLOGICAL EVIDENCE FROM MARS ?

Genetics of Eukaryotic Algae

The genetic aspect of eukaryotes or eukaryogenesis, eukaryotic evolution and probable geological and palaeoxibiological possibilities from Mars has been discussed by Chela-Flores (1996). According to Lynn Margulis (1970) eukaryotes evolved from symbiotic association between free living prokaryotes each giving rise to mitochondria, to chloroplasts or to parts of the flagella. The presence of "Spot Cells", spheroidal unicells with intra cellular organic matter, tetrahedral tetrads, filamentous microfossils, large sphaeromorphs, acritarchs and Vendotaenids (megascopic carbonaceous ribbon like fossils) is the main criteria for the recognition of the eukaryotes (Tewari 1996b). Eukaryogenesis may have occurred on Earth during Palaeoproterozoic time (2-1.8 Ga) but fossil evidences from rocks are not enough to support it. However, Mesoproterozoic (1.6 - 1 Ga) and Neoproterozoic (1.57 Ga) fossil records strongly supports the transition of life on Earth. The recent discovery of triploblastic metazoans from Lower Vindhyans as early as 1.1 billion years ago suggest that animals must have existed during Mesoproterozoic time (Seilacher *et al.*, 1998). The molecular palaeontological evidences indicate that prokaryotes lack nuclear membrane, mitochondrion and the chlorplast and its DNA is normally a single ring shaped chromosome which is not grouped with proteins. Eukaryotes have their DNA linked in Chromatin, the main organelles are normally in its cytoplasm (Chela Flores, 1994). The detailed study of multicellular brown algae Vendotaenids may give more information on the origin of eukaryotic algae. Seckbach (1994a) studied the red algae (rhodophytes) *Cyanidium caldarium* in detail for its genetic aspects. The Pre-Rhodophyta (Cyanidiophyclea) is a transitional algal group between cyanobacterial and Rhodophyta (Seckbach, 1994b).

SEARCH FOR EXTRATERRESTRIAL STROMATOLITES (SETS) - AND ALGAE

A comparative study of possible origin of life on Earth and Mars reveals that similar conditions would have been present on Mars supporting a probable occurrence of microorganisms on Mars (Mckay, 1997). The discovery of filamentous bacteria from Martian meteorite ALH 84001 and further presence of polyclic aromatic hydrocarbons, carbon and sulfur isotopic studies have indicated strong evidence for presence of fossilised life forms on Mars (McKay, D.S. *et al.*, 1996; Mckay, C.P. *et al.*, 1997). There is also possibility of finding fossil microbialites or stromatolites on Martian surface (Tewari, 1997). The discovery of microbial life or stromatolites from Mars will be the first definite evidence of fossil life on Mars and will be very useful for exopalaeontological or palaeoexobiological research. It is quite possible that stromatolitic buildups or microbial mats might have been covered under ancient Martian surface probably under the southern polar ice cover.

CONCLUSIONS

In conclusion, it is possible that the early stages of life (4-3.8 Ga) and early evolutionary processes like prokaryotic to eukaryotic changes must have been preserved on Mars as compared to Earth. Planet Earth has undergone Archaean-Proterozoic plate tectonics and earliest life forms must have been destroyed or not preserved due to very high grade metamorphism. Whereas Mars has been a stable lithospheric plate and has not moved laterally over

the Martian geological history. The potential of preservation of stromatolities, prokaryotic to eukaryotic algae, cyanobacteria and metazoans is more on Mars. A possible "Cambrian Explosion" of Martian life might have occurred on Mars similar to Earth but much earlier than Earth depending upon the oxygen level of the Martian atmosphere.

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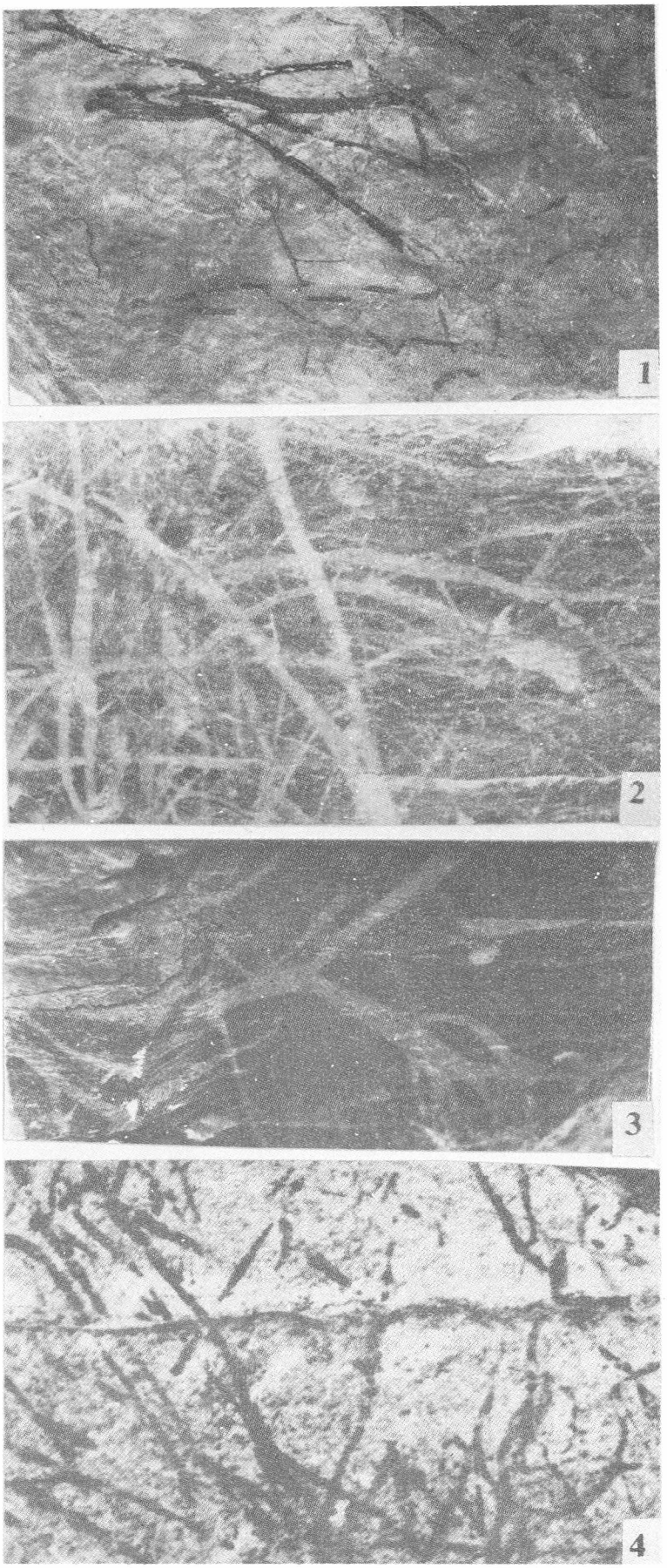
EXPLANATION OF PLATE

Plate 1 Impressions of algae Vendotaenids, *Tyrasotaenia* twisted and crumpled ribbons, specimen no. WIF/A-1303)

2. *Vendotaenia* sp. Specimen no. WIF/A-1307.

3. *Vendotaenia antiqua*, specimen no. WIF/A-1302

4. *Krolotaenia gnilovskayi* Tewari, Holotype WIF/A-1301.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