

## PROGRESS OF THE GEOLOGICAL EXPLORATION OF GREECE.

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THE geological investigation of Greece started shortly after the liberation of that country in the year 1830. A great number of geologists since then have studied the classical soil of Hellas. As in other Mediterranean countries, all of the pre-Tertiary rocks were at first attributed to the Cretaceous system, with a few local exceptions such as the Jurassic. At the turn of the last century this "Cretaceous" of the older authors began to be subdivided into numerous different formations so that, to date, all beds from the Silurian upwards are dated by paleontological evidence. Silurian and Devonian rocks are known only locally from the Anatolian coastal islands of Cos and Chios, viz., Silurian at Cos and Devonian at Chios. The Carboniferous—containing foraminifera, corals, brachiopods and gastropods—overlies unconformably the Devonian and can be subdivided into Moscovian and Upper Carboniferous. It extends over large areas in the Aegean region of Greece, e.g., in Chios, in Cos, in northern and middle Euboea, in the eastern Othrys, in Attica (including Salamis), and in the Argolian Archipelago with Hydra and its small surrounding islands. In the same regions the Carboniferous is followed conformably by the Permian, which can be subdivided into all its stages, based on the occurrence of foraminifera, corals, brachiopods, bivalves, and cephalopods. Moreover the Permian is present on the islands of Amorgos and Kuphonisia, which belong to the Cyclades archipelago.

The Lower Triassic is developed in Attica as the Werfenian group, of east Alpine facies, and at Chios as a red, siliceous, cephalopod limestone with a very interesting fauna. A few Alpine *Dinarites* are accompanied by a unique fauna which, up to date, is known only in Albania. To this fauna at Chios are added numerous Indonesian and western North American types such as *Pseudosageceras intermontanum* Hyatt and Smith,

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*Cordillerites angulatus* Hyatt and Smith, *Paranannites* div. spec., *Ingoites* n.sp., *Columbites parisiensis* Hyatt and Smith, *Columbites* ex aff. *plicatuli* Perrin Smith, *Columbites graeco-americanus* n.sp. and numerous other species of *Columbites* such as *C. malayanus* Renz, which were found in the Lower Triassic of Timor which is in the Malayan Archipelago on the route between the localities of Southeastern Europe and the Pacific States of America. The Middle Triassic, developed predominantly as *Diplopora* limestone, forms a great part of the mountain areas of eastern Greece. Beside that in the Othrys mountains and the Argolis (including the island of Hydra) red, cephalopod limestones of "Hallstatt facies" with very rich ammonite faunas occur. The cephalopod deposits of the Argolis range in age up to the middle Carnian. The Upper Triassic (partly dolomitic) formed as *Halobia*, *Megalodon*, coral and *Gyroporella*-limestones, spreads over the whole country as far as the Ionian Islands.

The same can be said of the Jurassic in which, without interruption, all stages and zones are proven by fossils. The lower and middle Liassic of Western Greece contain at a few localities brachiopods and "Domeriano" ammonites, such as *Rhacophyllites*. The upper Liassic there occurs in two different facies: first, as Mediterranean "ammonitico rosso," containing a rich fauna of ammonites which occur also in the Argolis; and secondly, as black *Posidonia*-slates. The following series, the middle Jurassic, is represented by *Opalinum*, *Murchisonae* and *Humphrisianum*-limestones. The latter is generally overlain by *Posidonia*-cherts, which occur in the Ionian part of Greece. These cherts cover the period from the Bathonian to the Callovian. In the Upper Jurassic of western Greece *Aptychus* beds and *Calpionella*, *Cadosina*, and *Stomiosphaera*-limestones of the Tithonian are present together with local occurrences of cephalopod limestones containing *Aspidoceras*, *Perisphinctes* and many other ammonites. In eastern Greece, including the central Peloponnes and Crete, the Kimmeridgian is developed as *Cladocropsis*-limestone and the Tithonian as *Ellipsactinia*-limestone.

The Cretaceous is also represented in all its stages, among which the *Hippurites*-limestones have been known longest. Within this formation the micropalaeontologic investigation has rendered the most important results. In the Lower Creta-

ceous the *Calpionella* and *Coscinoconus*-limestones must be mentioned. In the Middle and Upper Cretaceous, Cenomanian *Orbitolina*-limestones and *Orbitoides*-limestones of Maestrichtian age are important. The subdivision based on *Globotruncana*, which has been developed by O. Renz in Italy, has shown the same results all over Greece. From the Cenomanian up to the Maestrichtian the same succession of the different *Globotruncana* forms are observed. On account of its contents of foraminifera the lower Tertiary can also be subdivided into Palaeocene, Ypresian, Lutetian and Priabonian. The limestone facies is overlain by a Flysch facies which, in the uppermost part, consists of *Lepidocyclina* beds of Aquitanian age and layers of *Miogypsina*.

In the western part of Greece the sedimentation is continuous from the Middle Triassic up to the end of the Flysch (*Miogypsina* beds.) In the eastern part the sedimentation is continuous from the beginning of the Middle Triassic, but is interrupted in the Cretaceous. In the east Hellenic zone, an interruption in the sedimentation has been observed within the Cretaceous which corresponds to the Gosau transgression. It starts locally in the Cenomanian, whose basal deposits then contain rich coral faunas with *Aspidiscus* (*Aspidiscus cristatus* Lam., *A. felixi* Renz).

Proceeding from western Greece to the eastern part of the country, the above sketched subdivisions are subject to several changes in facies. In the northern part of Greece the strike of the facie zones runs parallel with that of the Dinaric Alps. Towards the middle and southern part of the country it bends gradually towards the east. The limits of these facies zones generally conform to the limits of the tectonic units. From the western and southern border of continental Greece, and from the adjoining islands towards the Aegean area, the following facies zones and respective tectonic units can be distinguished:

1. *The Paxos zone* forming the continuation of the Apulian Table is developed in the Ionian islands of Paxos, Antipaxos, Kephallenia, especially in the Aenos mountains, and in the western mountain range of Zante.
2. *The Adriatic-Ionian zone*, built up of simple fault slices and scales directed westerly, can also be regarded as autochthonous. Coming from the central Apennin and the Adria, it

embraces southwestern Albania, Epirus, Acarnania and the western coastal part of the Peloponnes and the other Ionian islands, including the southeastern range of Kephallenia. An uninterrupted sedimentation from the Carnian to the Aquitanian is present within this area.

The Adriatic-Ionian zone follows the external border of Greece and reappears in accordance with the general strike of the zones in the islands of Crete and Rhodes as "Ethia beds" and, furthermore, in the north of the island of Cyprus as "Lapithos beds." At Cyprus, the "Lapithos beds," including the conformably overlying Flysch, represent the basal formation. Over these sediments relicts of Middle Carboniferous, the whole Permian, and parts of Triassic, Jurassic and Cretaceous systems are overthrust.

3. *The Tripolitza zone* consists of dark limestone and dolomites which represent a continuous succession from the Triassic to the Lutetian. The last is followed by Flysch sediments, which include locally a basal foraminiferal limestone of Priabonian age. This zone occurs in the central part of the Peloponnes, at the islands of Kythera, Antikythera, Crete, Kasos and Rhodes.

4. *The Olonos-Pindos zone* includes a continuous succession of sediments from the Middle Triassic to the end of the Flysch. It consists of *Diplopora*-limestone and of a following series of variegated slates alternating with cherts and platy limestones. This series begins with *Halobia* beds of the middle Carnian and ends with *Orbitoides* beds of Maestrichtian age. A Flysch formation overlies conformably this complex of cherts, slates, and limestones which, locally, also is connected with intrusions of spilites and other igneous rocks with their respective tuffs. This zone builds up the Pindos chains in Thessalia and Aetolia and continues southward through the Peloponnes, Kythera, Crete and Rhodes towards southern Asia Minor. In the Pindos Mountains the predominant structure is a succession of slices which are overthrust westward over the western Aetolian Flysch. Southward in the Peloponnes these scales pass over into nappes.

5. *The Parnass-Kiona zone* is characterized by a continuous limestone sedimentation from the Anisian (Bulog limestone) to the Danian. Within the Cretaceous the sedimentation is

interrupted by an emergence. Bauxite deposits were formed during this period.

6. *The eastern Hellenic zone* is distinguished mainly by a serpentine-slate-chert group. The age of these rocks ranges from the Jurassic to the Lower Cretaceous. The sedimentation of the eastern Hellenic zone is interrupted by the already mentioned Gosau and Cenomanian unconformity. This zone and the Parnass-Kiona zone are distributed in the eastern regions of the country and form, together, the nappes of the eastern mountains of Greece. The Olonos-Pindos, the Parnass-Kiona and the eastern Hellenic zone run conformably to the general strike and turn, in the southern part of the country, toward the east. Thus they reappear in southern Anatolia and enwrap the crystalline basements of the Aegean area.

7. *Basements.* Crystalline rocks form the Central-Peloponnesian-Cretic, the Attic-Cycladic and the Pelagonic massifs. About the age of the crystalline formations no precise indications can be given as no organic remains are preserved. The older authors considered these formations partly as pre-Carboniferous, partly as Cretaceous. Finally, J. Trikkalinos regards their age as pre-Carboniferous. The metamorphic basement rocks are overlain unconformably by the upper Palaeozoic and Lower Triassic.

The exploration of the upper Tertiary and Quaternary of Greece is advanced recently by M. Mitzopoulos and the knowledge of the different soils by N. Liatsikas.

Besides the undetermined stratigraphical division of the metamorphic basements, the stratigraphy and the tectonic of the non-metamorphosed sedimentary rocks in its main lines are well recognised.

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A detailed list of references is to be found in these two publications.

BASLE, SWITZERLAND.

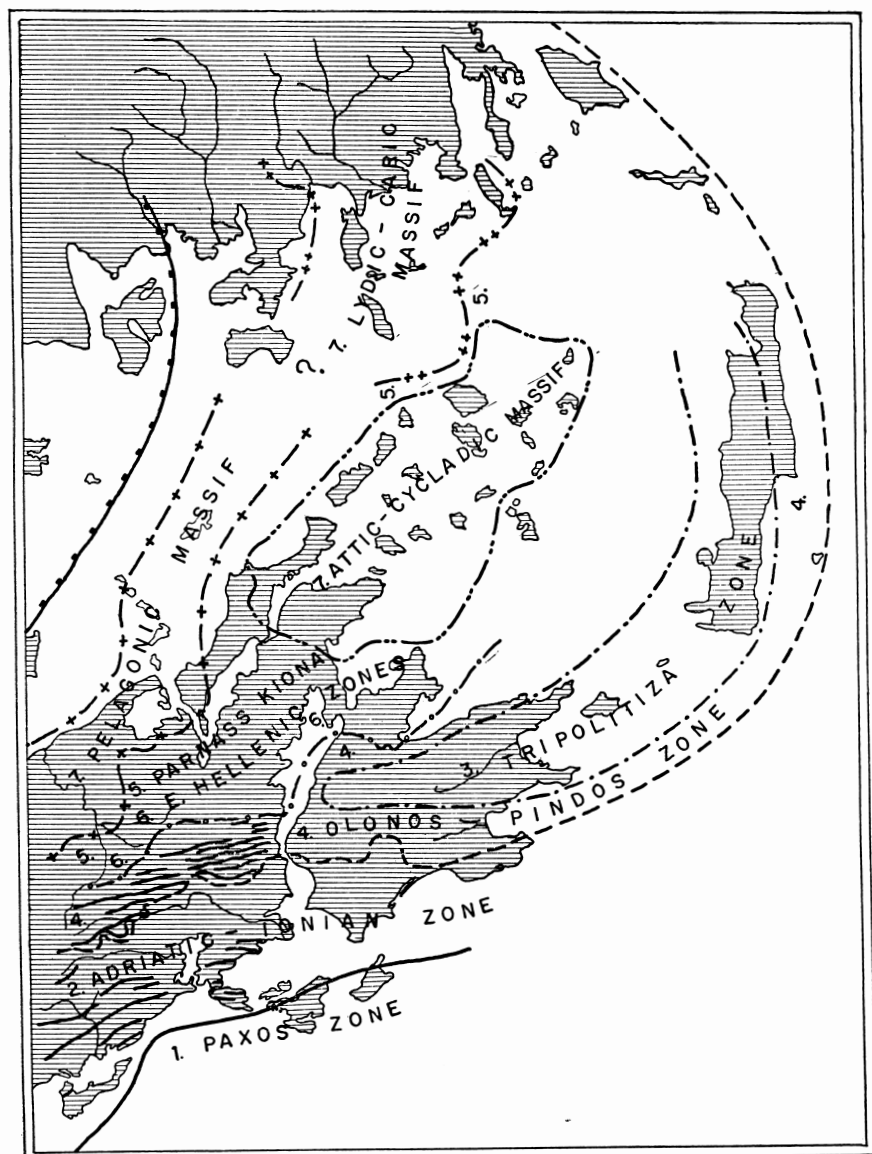


Fig. 13—Map of Greece, showing the distribution of the main facies zones.