SEDIMENTOLOGICAL STUDY OF THE TRIASSIC SOLUTION-COLLAPSE BRECCIAS OF THE IONIAN ZONE (NW GREECE)

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ABSTRACT: The Triassic Breccias of the Ionian zone are typical evaporite dissolution collapse breccias. Several features indicate the pre-existence of evaporites, while alternation of dolomites and evaporites consist a very common association in the subsurface.

Brecciation took place in two principal brecciation stages. The first brecciation stage started soon after deposition, during a period of subaerial exposure due to periodic seasonal desiccation and small-scale meteoric removal of intrastratal evaporites. During this stage, the carbonate beds suffered in-situ breakage and carbonate mud infiltrated into fractures.

Shortly after, a major brecciation event occurred, that affected the still non-well lithified carbonate fragments, due to progressive dissolution of evaporites by meteoric water. Carbonate mud continues to be infiltrated in-between the breccia fragments. In the same time, intensive calichification processes were responsible for further brecciation and reworking of the brecciated carbonate beds locally sediments, testifying a period of temporary regional emergence (paleosoil).

The breccia matrix is characterized by microbreccioid appearance, resulting from internal brecciation of the coarser clasts. Due to early calichification, the matrix becomes enriched in oxidized clays and by pronounced calichification tends to assimilate the breccia clasts, being gradually transformed into a calcrete with floating texture.

Clasts microfacies types include phytoclasts with strongly impregnated by Fe-oxides laminae (laminar calcrete), carbonized plant tissue, lime and dolomitic mudstones with evidence of former evaporites (dolomite/calcite pseudomorphs after gypsum and/or void-filling anhydrite cement, molds after evaporite nodules, euhedral quartz crystals etc.), carbonate fragments pseudomorphic after evaporites, pelsparites/intrasparites, recrystallized dolomites and dedolomites.

The predominance of shallow intertidal to supratidal carbonate fragments, indicates that the strata that gave birth to the breccia, formed in a very shallow, restricted, hypersaline, lagoonal setting, evolved into sabkha sequences in the frame of a lowstand episode. Sedimentation of dolomite and evaporite is considered that has taken place during arid periods, while meteoric water influx during the wetter intervals. During that lowstand episode, that resulted in a hiatus interval, the breccias have suffered intensive calichification. Circulating pore-fluid brines resulting from evaporation, provoked syngenetic to early diagenetic dolomitization of muds, by increase of molar Mg/Ca ratio and provided ions for evaporite nodules / crystal growth.

Post-Pliocene to Recent subaerial exposure of the carbonate breccias, led to intensive soil-forming processes, active till today, that accentuated the brecciated appearance of the formation. These processes are responsible for the formation of porous carbonate breccias, the so-called "rauhwackes".

INTRODUCTION

The study of the sedimentary and diagenetic fabrics of the carbonate breccias, provides significant key to the interpretation of the depositional setting, as well as to the recognition of post-depositional processes, e.g. tectonic- or karstification events (Blount and Moore 1969).

An important breccia type, is the so-called solution-collapse breccias, which often occupy extensive areas in the outcrop. These breccias result by solution of interlayered evaporites, either by meteoric or formation waters and collapse of the cavities produced after evaporite removal (Stanton 1966; Beales and Hardy 1980; Friedman 1997). For that reason former evaporites are not preserved or are recognized only in traces or in pseudomorphs. In such cases the presence of evaporites is inferred from subsurface data (McWhae 1953; Middleton 1961; Friedman and Shukla 1980; Mamet et al. 1986; Claeys et al. 1988; Swennen et al. 1990).

In the present study, sedimentary and diagenetic fabrics from the Triassic Breccias formation of the Ionian zone are presented, both from cuttings and cores, as well from outcropping material. The solution-collapse origin of these breccias has been confirmed in previous studies by abundant data, for former existence of evaporites, derived from outcropping material (Pomoni-Papaioannou 1980; Pomoni-Papaioannou and Dornsiepen 1987). For first time cuttings and cores material is studied, attempting to clarify the precise time of brecciation and calichification e.g. whether they represented syndepositional or post-depositional processes.

The examined material includes in some cases a high percentage of sedimentary organic material (phytoclasts), which yields additional information on palaeogeography and diagenesis, mostly concerned with the petroleum source rocks research, performing in the area of Western Greece (Karakitsios and Rigakis 1996).

STRATIGRAPHICAL AND STRUCTURAL SETTING

The Ionian zone of northwest Greece (Epirus region), constitutes part of the most external zones of the Hellenides (Paxos zone, Ionian zone, Gavrovo-Tripolis zone; Fig. 1A). The rocks of the Ionian zone range from evaporites (Triassic), through a varied series of carbonates, shales and cherts (Jurassic through upper Eocene), followed by flysch (Oligocene) (Fig. 2).

Evaporites are well developed in the subsurface. Deep drilling in search of hydrocarbons proved the existence of evaporitic formations, mainly consisting of alternating sulphate and carbonate sediments (IGRS-IFP 1966). On the contrary evaporites are rare in outcrops, consisting of small gypsum bodies which are always accompanied by extensive carbonate breccias, known as Triassic Breccia formation (IGRS-IFP 1966; BP 1971). Generally, gypsum and associated breccias crop out in areas aligned with or near to major thrusts or faults, while in many cases they are injected through fault or thrust surfaces and they may cover much more recent formations (e.g. Burdigalian).

The "pre-evaporite beds" of this zone do not crop out, nor they have been penetrated by boreholes (IGRS-IFP 1966; BP 1971). The evaporites are overlying by the Foustapidima Limestone of Ladinian-Rhetian age (Renz 1955; Karakitsios and Tsaila-Monopolis 1990), followed by the shallow water Pantokrator limestones of early Liassic (Aubouin 1959; IGRS-IFP 1966; Karakitsios 1992 1995).

Gypsum outcrops were in the past considered of Pliocene or Messinian age. Bornovas (1960) first suggested the pre-Carnian age of the evaporites, based on detailed observations in Lefkas island. More recently, the evaporite outcrops have been directly dated by the discovery in Epirus of early-middle Triassic Foraminifera in dolomites intercalated into gypsum deposits (Pomoni-Papaioannou and Tsaila-Monopolis 1983; Dragastan et al. 1985).

At the surface anhydrite, that is the rule in the boreholes, never crops (IGRS-IFP 1966). Rock salt associated with gypsum was in the past explored at Monolithi, in the eastern limb of Mount Xerovouni.

The breccias are typically unbedded rocks consisting of recemented angular fragments of limestones and dolomites - foetid, grey-brown to black and vuggy. The gypsum beds can be exemplified from some rare exposures as the one of Vritsela hill, at about 8 km north of Igoumenitsa (Fig. 1B), where breccias and associated gypsum are well exposed. Gypsum occupies the central part of the hill, while breccias the extensive periphery of the hill. Gypsum crops out under microcrystalline or flake form, white to gray in color, with rotated black or red traces, in confused masses into the breccias. Two main lithological types are distinguished: the massive gypsum and the stratified gypsum, with rare dolomites intercalations (Pomoni-Papaioannou 1983, 1985).

The evaporites played a capital role in the tectonic evolution of the Ionian basin (Karakitsios 1995): a) during Middle Lias the evaporitic Ionian substratum halokinesis influenced the intense block-faulting which affected the early Liassic shallow platform (Pantokrator limestones) and resulted in the formation of several small, structurally controlled basins, b) during compressional tectonics of Alpine orogeny, the preexisting extensional structures (from Pliensbachian

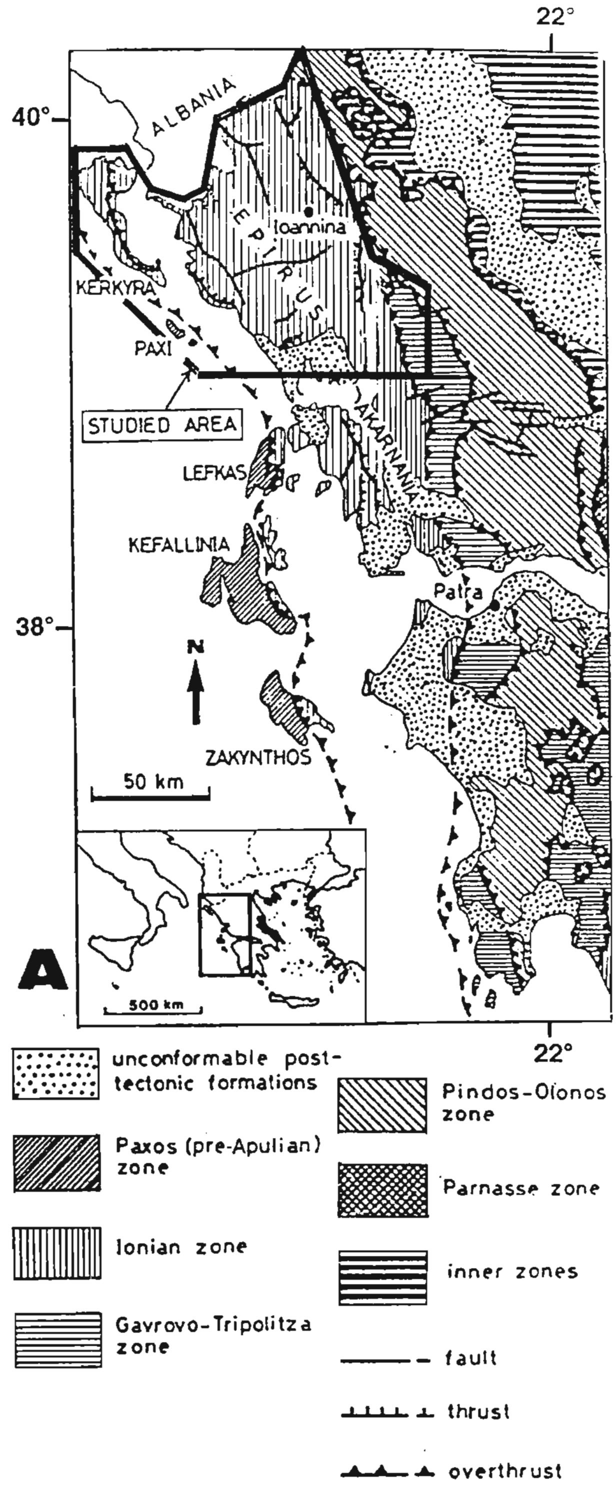

Figure 1. (A) Structural map of western continental Greece (after Karakitsios, 1995).

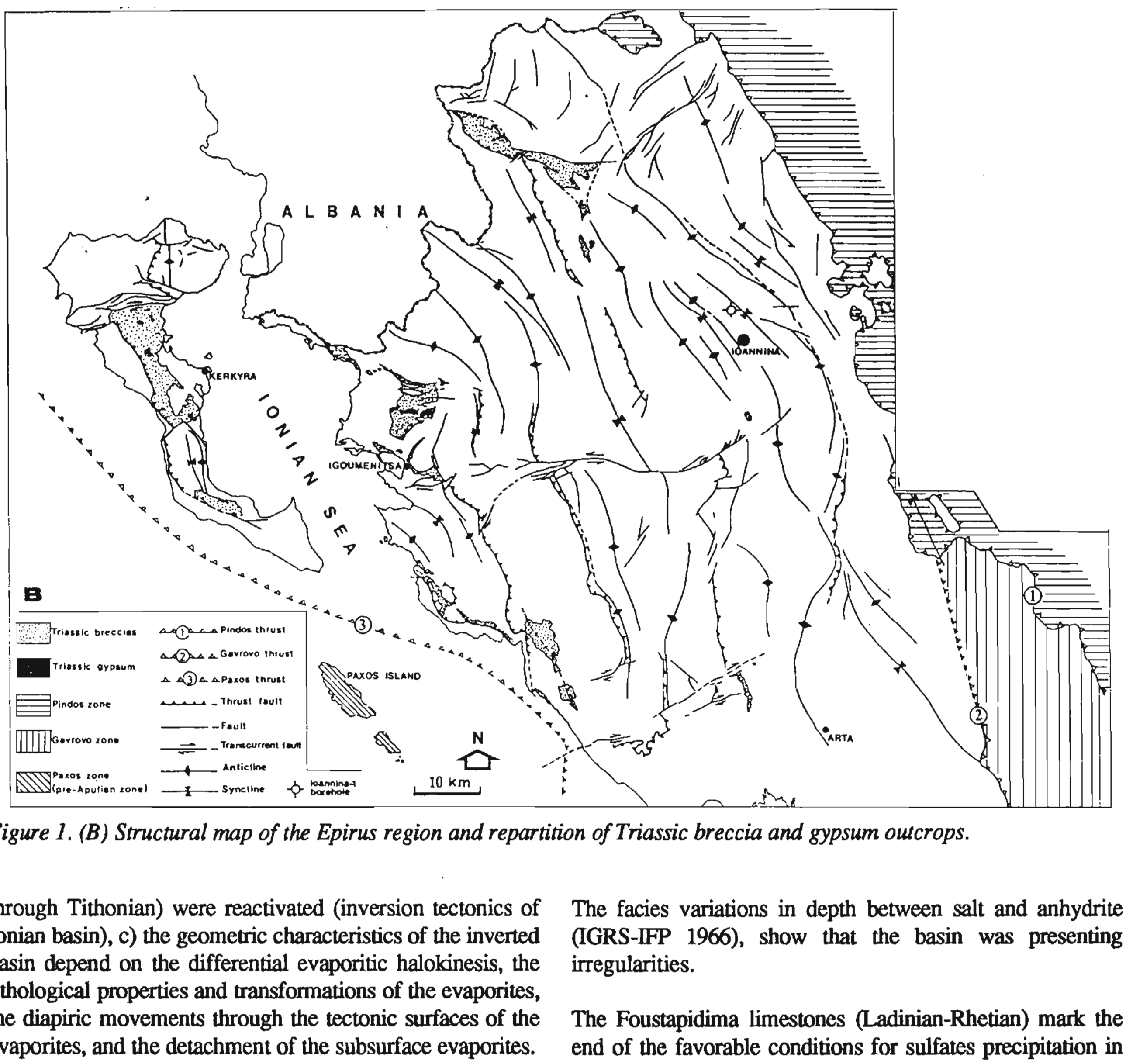

Figure 1. (B) Structural map of the Epirus region and repartition of Triassic breccia and gypsum outcrops.

through Tithonian) were reactivated (inversion tectonics of Ionian basin), c) the geometric characteristics of the inverted basin depend on the differential evaporitic halokinesis, the lithological properties and transformations of the evaporites, the diapiric movements through the tectonic surfaces of the evaporites, and the detachment of the subsurface evaporites.

The boreholes in Ionian zone penetrated in some cases more than 3000 m of evaporites, proving the great thickness of the evaporitic series (IGRS-IFP 1966; BP 1971. However, the initial thickness of the evaporitic basin owes to be lesser, because all the boreholes have been drilled in anticline zones, where diapiric phenomena are intense (Karakitsios 1992). Analogous evaporitic series are known in the Paxos (Preapulian) zone, where the evaporites are found higher in the stratigraphical column, into the Liassic limestones (IGRS-IFP 1966; BP 1971), in Italy in the Cargano (Carissimo et al. 1963), in the Tuscan-Umbrian domain (Ciarapica et al. 1987), and in Yugoslavia. These extensive evaporite deposits suggest that a huge evaporitic basin was existing in all this region. Modern sedimentary environments lack examples of such a great evaporitic basin. Actual evaporites are formed in lagoons (e.g. sabkhas of north Africa) or deltas. However, the geological data allows to do the following remarks:

The facies variations in depth between salt and anhydrite (IGRS-IFP 1966), show that the basin was presenting irregularities.

The Foustapidima limestones (Ladinian-Rhetian) mark the end of the favorable conditions for sulfates precipitation in Ionian domain and the installation of a marine sedimentation, being continued by algal limestone sedimentation (Pantokrator limestones). In contrast, in the Paxos (Preapulian) zone evaporite conditions persisted until the Liassic, as the anhydrite intercalations in the Liassic limestones, suggest.

The studied breccias derive mainly from cores and cuttings of the Ioannina-1 borehole and secondary from outcrops of the entire Ionian basin of Epirus region (Figs. 1B and 3). The Ioannina-1 borehole drilled to a total depth of 1530 m in Ioannina (Fig. 3). The stratigraphy of the borehole, determined from cutting and cores, is as follows (Karakitsios 1995): from 0 to 300 m Quaternary and Neogene sediments, from 300 to 610 m Vigla limestones, from 610 to 1000 m non differentiated Posidonia beds, from 1000 to 1150 m Siniais limestones, from 1150 to 1245 m Pantokrator limestones, and from 1245 to 1530 m "Triassic breccias". Because the Pantokrator limestones thickness is generally more than 1000 m thick, the contact between Pantokrator limestones and

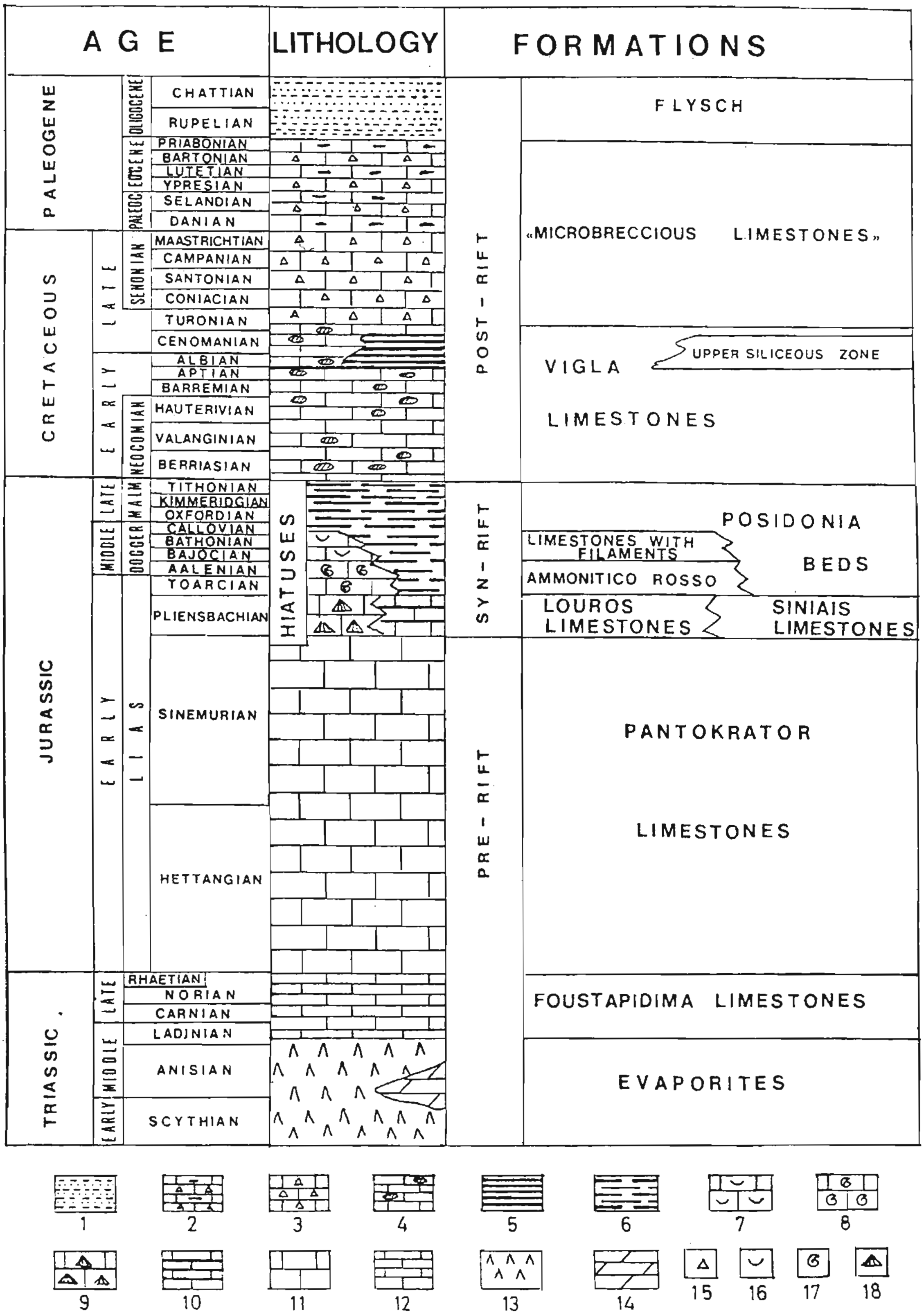

Figure 2. Representative stratigraphic column of the Ionian zone (after Karakitsios, 1995): 1= pelites and sandstones; 2= cherty limestones with clastic material; 3= pelagic limestones with clastic material; 4= pelagic cherty limestones; 5= cherty beds with green and red clay, sometimes shaly; 6= pelagic limestones, marls, and siliceous argillites; 7= pelagic limestones with pelagic lamellibranches; 8= pelagic, red, nodular limestones with ammonites; 9= micritic limestones with small ammonites and brachiopods; 10= pelagic limestones; 11= platform limestones; 12= platy black limestones; 13= gypsum and salt; 14= dolomites; 15= breccia; 16= section of pelagic lamellibranch (filament); 17= ammonite; 18= brachiopod.

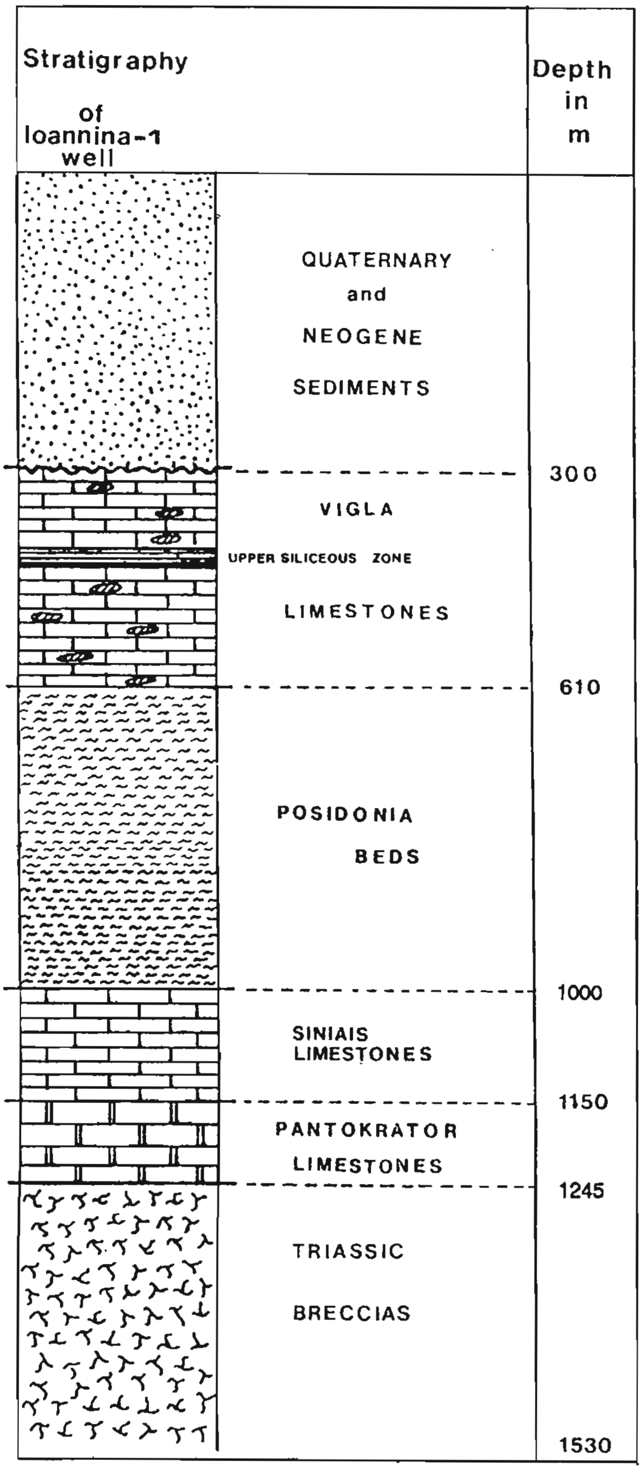

Figure 3. Stratigraphy of the Ioannina-1 borehole (for location, see Fig. 1A) (modified after Karakitsios and Rigakis, 1996)

underlying breccias might be tectonic (Karakitsios 1995). The Ioannina-1 borehole permitted us for first time to study the breccias in a depth greater than 1200 m. This depth excludes the influence of post-nappe subaerial exposure of the rock in the mechanism of brecciation, so that the observed lithological characters are primary.

GENERAL DESCRIPTION OF THE BRECCIAS

The studied material is derived from two cores in 1523 m and 1250 m, respectively, and from cuttings from the in-between depths. Outcropping material was studied as well. Although detailed microscopical analysis of borehole and outcropping material revealed several textural similarities and differences, in all cases carbonate breccias show evidence of evaporite solution-collapse origin. The carbonate breccias in the depth of 1523 m (core A) are oligomictic, consisted mainly of subspherical-subangular, dark greyish-brownish, dolomitic clasts. In contrast, the principal characteristic of the breccia in the depth of 1250 m (core B), is the high amount of phytoclasts.

Morphologically and according to the descriptive field classification of Morrow (1982), the studied carbonate breccias correspond to particulate to cemented mosaic packbreccia. They constitute a complex series, consisting mainly of calcareous-dolomite breccias, cellular dolomites, dark blue to black cavernous dolomitic limestones, reddish platy dolomites and fragments of black sublithographic limestones.

Four (4) types of dolomite are distinguished, based mainly on their crystal size and crystal boundary shapes. These dolomite-types correspond to different dolomitization stages, through the time scale. The terminology proposed by Sibley and Gregg (1987) is used, which is based largely on the fundamental classification of Friedman (1965).

Core Material-Clasts Microfacies Types

Dolomitic mudstones.-- They consist of a structureless, chaotic fabric, sized from millimeter to centimeter and occur only in core A (Fig. 4). Clasts show crumbled edges, assuming that they were not-lithified yet. and can often be refitted each to other, suggesting an intraformational origin (Fig. 4). Breccia clasts often show indices of irregular and circumgranular cracking, due to dessication (Figs. 5 and 6). They are surrounded and transected by sinuous irregular micritic sheaths of variable thickness and arrangement, which after dissolution remain and tend to form a net (Figs. 4 and 6).

The dolomitic mudstone clasts are uniform, consisting of finely crystalline equigranular dolomite, characterized by dense and sucrosic textures (Type-1 dolomite). This dolomite type, displays a xenotopic fabric, consisting of tightly interlocking anhedral crystals (4-10 μm), which appear turbid in plane light (Figs. 4 and 6). These dolomites occur in close association with pseudomorphs after evaporite nodules and/or crystals (Fig. 7). However, due to evaporites dissolution, only the habit of the preexistent evaporite crystals is preserved. Voids resulted are filled by blocky dolomite cement, in which rectangular-shaped crystal ghosts have been recognized, considered as outlines of former void-filling anhydrite crystals (Fig. 8). The prismatic habit of anhydrite, as well as its

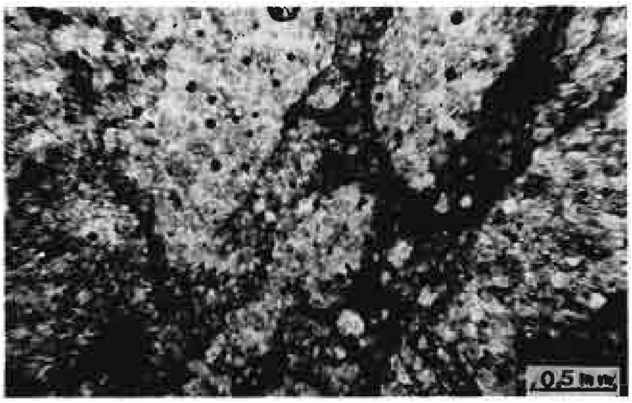

Figure 4. Oligomictic carbonate breccias, consisting of structureless mudstones with a chaotic fabric. Clasts show crumbled edges and can be refitted each to other. Sinuous, irregular micritic sheaths of variable thickness and arrangement surround and transect the breccia clasts. Note the xenotropic fabric of dolomite. Crystals are anhedral, tightly interlocking and appear turbid in plane light.

Figure 5. Clasts surrounded by cirumgranular cracks.

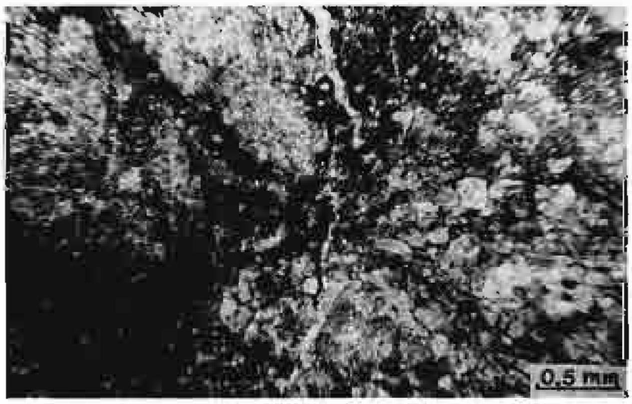

Figure 6. Irregular thin desiccation cracks transect or surround the clasts. Sinuous, irregular micritic sheaths transect the breccia clasts.

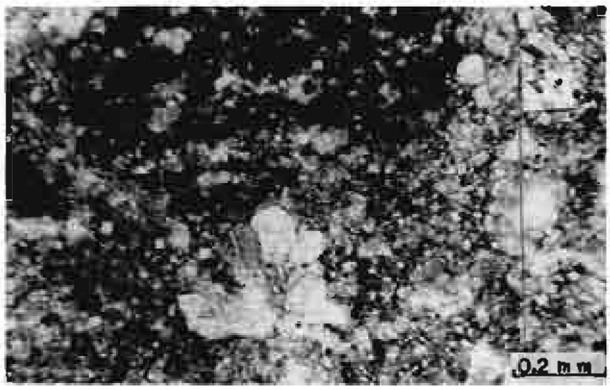

Figure 7. Pseudomorphs after evaporite nodules, consisted of radially arranged crystals.

Figure 8. Pseudomorphs of blocky dolomite after void-filling anhydrite. Note the characteristic prismatic habit of anhydrite crystals.

rectangular cleavage and straight extinction, is still distinguished. In places concentrations of lensoid dolomite crystals, representing pseudomorphs after gypsum, are observed (Fig. 9). Often islets consisting of a mosaic-like idiomorhic dolomite crystals occur, with characteristic cauliflower outlines (chicken-wire fabric), reminding nodules of preexistent anhydrite (Fig. 10). In places, quartz euhedra with a tendency of radial arrangement (Fig. 11).

Replacement dolomites.-- In lesser amounts, clasts of recrystallized replacement dolomite (dolomicrospar/dolopseudospar) are observed (Type-2 dolomite), consisting of a mosaic composed of subhedral crystals, with brownish cores (Fig. 12). Dolomite of this type is composed of tightly packed subhedral- to anhedral crystals, with xenotopic fabric, averaging in size between 30-100 μm and is observed in both cores. Dolomite crystals are dusty, characterized by dark brownish, inclusion-rich cores and clear, inclusion-free rims. The dark amorphous material of the crystal cores, is inferred to be organic. Due to recrystallization, possible pre-existent allochemical constituents and sedimentary structures are no more recognized. Dolomite is either a diagenetic-replacement dolomite, resulting after slight burial of the formation or has resulted by neomorphism of syngenetic or early diagenetic

Figure 9. Dolomite pseudomorphs after dispersed lensoid like gypsum crystals.

Figure 10. Pseudomorphs of mosaic-like dolomite after evaporites with characteristic cauliflower outlines.

Figure 11. Radial arrangement of quartz crystals.

dolomite (Sibley and Gregg 1987; Amthor and Friedman 1991).

Dedolomites.-- In both cores occur clasts consisted of anhedral calcite crystals, in the form of a dense mosaic, with tiny relics of dolomite rhombohedra. Dedolomite fragments have suffered meteoric dissolution.

Figure 12. Replacement dolomite of Type-2, consisting of subhedral crystals with brownish cores. Clasts lack of relic sedimentary structures.

Figure 13. Phytoclast resembling to biogenic laminar calcretes.

Phytoclasts.-- They occur only in core B, varying in size and shape, averaging from 1-5 mm. They are texturally similar with the planar, non-skeletal stromatolites (algal boundstones) and with the biogenic laminar calcretes (sensu Wright et al. 1988) (Figs. 13 and 14). Due to disseminated organic matter, many phytoclasts are dark in color (Fig. 15). Evidence of subaerial exposure and pedogenic modification consists the orange-reddish color of many phytoclasts.

Laminae are millimeter sized, undulated and irregular and during their growth have incorporated host rock material. Laminae are subliniated by the alignment of small dolomite rhombohedra, along them, resulting to a banding texture (Fig. 16). Banding is further accentuated by chromatic differentiation of the alternated laminae, due to different degree of organic staining. In places, anastomosing, sinuous, as well as laterally bifurcated sheaths are distinguished.

Some phytoclasts are characterized by a micronodular texture, nodules being consisted of an equigranular mosaic of crypto-microcrystalline carbonate (Fig. 17). In places, the observed micronodular texture, reminds the "alveolar" structure of

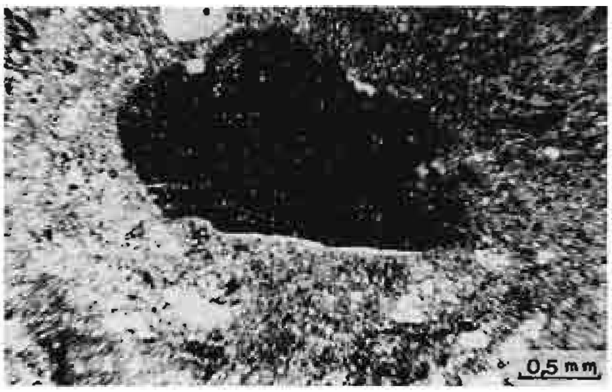

Figure 14. Phytoclasts are texturally similar with the planar, non-skeletal stromatolites.

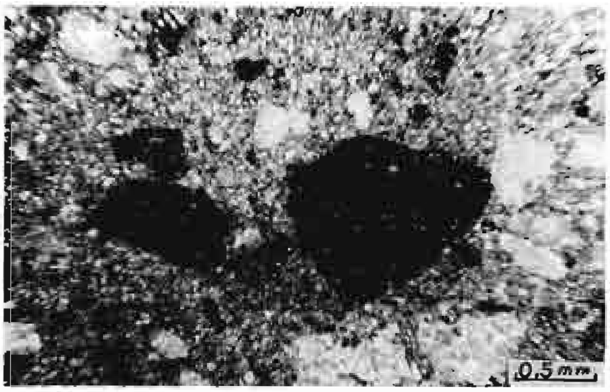

Figure 15. Carbonate breccia rich in phytoclasts. Phytoclasts are dark in color, due to disseminated organic matter.

rhizolites (Klappa 1980). An internal structure can be visible in some phytoclasts, by differentiation of an external part consisting of concentric coatings (rhizoconcretion) and an internal part -core of the phytoclast- consisted of an amorphous opaque material (Fig. 18).

However it should be also mentioned, the presence of carbonized opaque and semi-opaque, plant tissues fragments. These phytoclasts consist of fairly resistant to biodegradation material. It is important to notice here, that the analysis of a pure shale fragment from a core at 1250 m and from handpicked shale fragments, in the interval 1250-1270 m indicated a very high TOC content (8 to 11,15%); the organic matter (Type I) is also of very good quality (Karakitsios and Rigakis 1996).

The breccias matrix is micritic, with abundant, very fine to fine crystalline, scattered dolomite rhombs. It is characterized by microbreccioid appearance, resulting from internal brecciation of the coarser clasts and for that reason a gradual transition between clasts and matrix is observed (Fig. 19). Part of the matrix of the breccias consists of very fine to fine crystalline, subhedral to anhedral crystals (Type-3 dolomite).

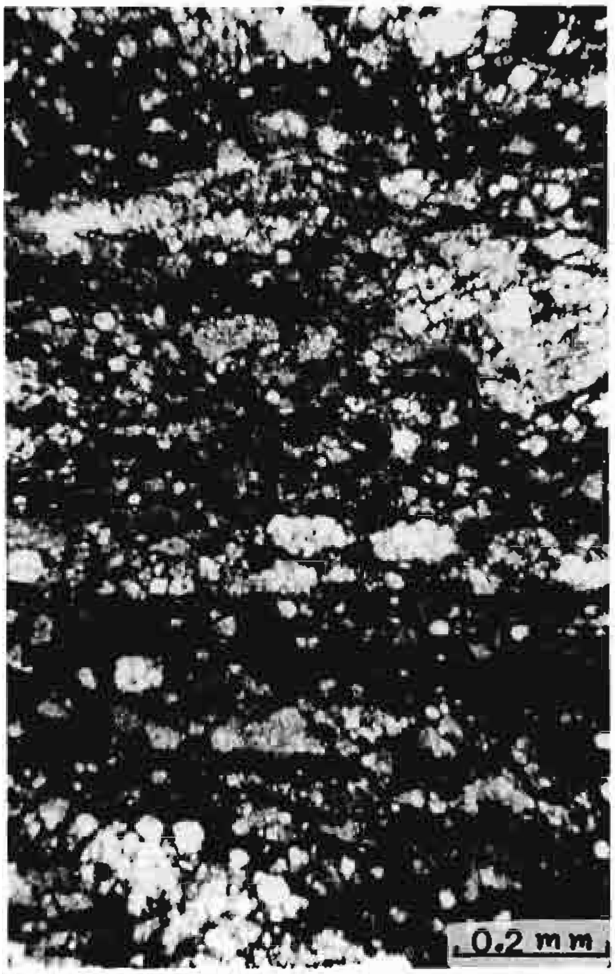

Figure 16. Phytoclasts consisting of undulated and irregular laminae. Laminae are subliniated by small dolomite rhomboedra resulting to a banding texture. Due to different degree of organic staining banding is further accentuated.

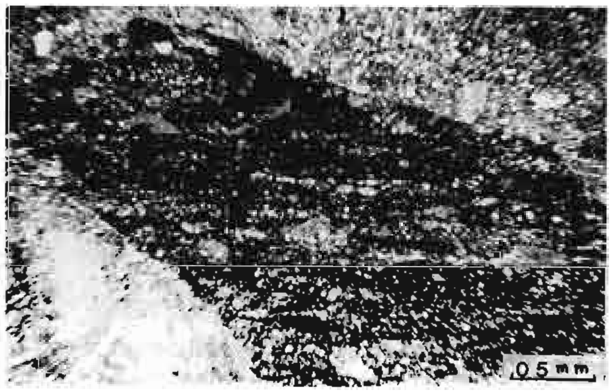

Figure 17. Phytoclast with micronodular texture. Nodules are consisted of crypto-microcrystalline carbonate. The micronodular texture, reminds the "alveolar" texture.

This material has been introduced mechanically after the first brecciation episode, into cracks and open spaces of the breccias.

Figure 18. Phytoclast differentiated to an external part consisted of concentric coatings and an internal part, consisted of amorphous opaque material.

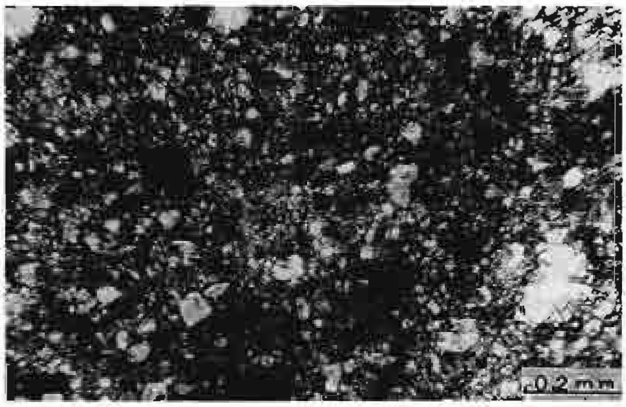

Figure 19. Matrix of the phytoclast enriched carbonate breccia. Note the characteristic microbreccioid appearance.

Open spaces or fractures of breccias are cemented by elongated, and colorless in plane light, medium to coarse subhedral crystals, with plane crystals faces, averaging in size between 200-500 μm, (Type-4 dolomite). This dolomite type is considered as a second-matrix generation Crystals show the textural features of pore-filling dolomite, being normally orientated on the clasts walls and often showing a crystal size increase toward the center of the intergranular pore. Relic material or replacement features lack. Some crystals show the characteristic prismatic habit and rectangular cleavage of anhydrite.

By pronounced calichification, the matrix tends to assimilate gradually the breccia fragments, being transformed to a calcrete with floating texture, enriched in oxidized clays (Fig. 20). Calichification starts by formation of non-isopachous coatings of Fe-oxides around the breccia fragments, in cases boring them.

Cuttings Material (1523 m-1250 m)

In cuttings material, all microfacies types, previously described, have been observed. Algal laminated mudstones

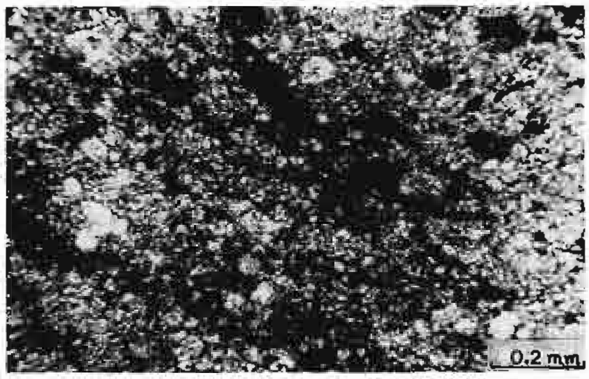

Figure 20. The matrix tends to assimilate gradually the breccia fragments, being transformed to a calcrete with floating texture.

and pelsparites / intrasparites (grainstones),are also included in the main microfacies types (Logan et al. 1974). They consist of micron-sized spheroidal peloids, with no internal structure, as well as of intraclasts and coated grains, of variable shape and size.

Outcropping Material

Due to long lasting vadose diagenetic processes, involving multiple dissolution, precipitation and alteration of host rock (dolomitic/dedolomitic solution-collapse breccias) different caliche facies developed depending on the degree of maturation.

These facies include rhizoconcretionary caliche, massive caliche and pisolitic caliche facies, that either represent a time sequence or correspond to synchronous stages of calichification (Pomoni- Papaioannou and Dornsiepen 1987).

THE SOLUTION-BRECCIATION PROCESS

Features within the breccia, such as re-brecciated fragments and the presence of two-matrix generations (Type-3 dolomite: mechanical introduced matrix and Type-4 dolomite: void-filling dolomite), indicate multiple phases of brecciation.

A minor initial stage of brecciation (first stage brecciation), occurred soon after deposition. During this stage the original carbonate beds locally fractured and carbonate mud infiltrated into fractures and open spaces between the fragments (Type-3 dolomite). This first brecciation stage could have resulted from small-scale dissolution of evaporites and from periodic seasonal desiccation under evaporitic conditions. According to Swennen et al. (1990), it cannot be ruled out that a volume decrease, as a result of gypsum-anhydrite tranformation, might have played a role.

A major brecciation event occurred shortly after sedimentation of the breccia formation, by infiltration of meteoric fluids and dissolution of evaporites interlayers, causing brecciation (second stage brecciation). This is inferred from the presence of incompletely lithified fragments, with crumbled edges and the infiltration of non-lithified carbonate mud (microspar), downwards between the breccia fragment. Finally the breccia fragments were cemented by blocky dolomite (Type-4 dolomite).

In the same time, intensive calichification processes, further reworked the brecciated sediments. Paleosol horizons and several soil-forming features testify to a period of temporary regional emergence. Early soil-forming features are recognized only in cuttings and cores, possibly because in outcropping material they have been overlapped by the recent pedogenetical features. Post-Pliocene to recent subaerial exposure of the breccias led to intense soil-forming processes active till today, that accentuated brecciation and produced characteristic pedogenic facies including alveolar structures, rhizoconcretionary, laminated, pisolitic caliche and fragments of Microcodium (Pomoni-Papaioannou 1980; Pomoni-Papaioannou and Dornsiepen 1987). These processes are responsible for the formation of porous carbonate breccias, the so-called "rauhwackes".

It should be mentioned that the Triassic collapse dolomitic breccias of Ionian zone appear many similarities with the extended Jurassic-Cretaceous dolomitic breccias of the Tripolis zone in the Mainalon Mt., which have been proved to be also of collapse origin (Pomoni-Papaioannou and Carotsieris 1993).

DEPOSITIONAL MODEL-DIAGENETICAL EVOLUTION

As the predominance of shallow intertidal to supratidal carbonate fragments indicates, the strata that gave birth to the studied brecciated carbonate formation formed in a very shallow, restricted, hypersaline, lagoonal setting, which evolved into sabkha sequences. The shale fragments, with significant content in organic matter, included rarely within the Triassic breccias (Karakitsios and Rigakis 1996) were initially deposited as layers in relatively shallow restricted sub-basins inside the evaporitic basin. The lack of detailed stratigraphy of evaporitic sequence in Ionian zone does not allow any suggestion about the stratigraphic level of the shale layers; consequently, it is not possible to correlate the deposition of these layers with any Triassic geological event (e.g. sea level change or local subsidence). However, the establishment of the evaporitic sedimentation in the entire basin favored the preservation of the organic matter (Powell 1986; Miller 1990). Consequently, the processes that formed the evaporite dissolution collapse breccias caused also the fragmentation of the initially organic rich shale layers, which are present actually as organic rich shale fragments in the Triassic breccias.

Sedimentation of dolomite and evaporite sequences is considered that has taken place during arid periods. During that lowstand episodes, that led to a hiatus interval, the breccias have been intensively affected by soil-forming processes. The presence of highly oxidized phytoclasts (laminar calcretes), further suggests a subaerial continental environment.

Examination of the regional, geological, petrographical and sedimentological data presented, reveals the following evolution pattern:

Taking into account the well-known spatial association between Triassic dolomites and evaporites in the Ionian basin, it is assumed that the fine-crystalline dolomite that consists the breccia clasts has been formed by penecontemporaneous or early replacement of preexisted calcareous muds, in a restricted near surface environment, by reflux of dense, hypersaline, Mg-rich brines (Adams and Rhodes 1960). In these sequences, upward-moving brines resulting from evaporation, provided ions for evaporite nodules / crystals growth.

For the subsequent diagenetic processes that have affected the sediments e.g. dissolution of evaporites, neomorphism of early fine-crystalline dolomite, calcitization of dolomites and collapse-brecciation, a significant recharge of meteoric groundwater is necessary. According to Peryt and Scholle (1996), the responsible, for the production of early calcitized dolomites, meteoric waters influx and percolation took place during wetter episodic sea-level falls.

Deep burial dolomitization, is not considered possible for the studied dolomites, as great volumes of water would be necessary to be transported and in addition no late-stage, saddle dolomite crystals were recognized.

CONCLUSIONS

The Triassic Breccias of the Ionian zone are evaporite dissolution collapse breccias. Former presence of evaporites is indicated by pseudomorphs after evaporites.

Clasts include mainly shallow intertidal to supratidal facies: dolomites with pseudomorphs after evaporites, algal laminates, pelsparites, and phytoclasts (laminar calcretes).

The above clasts microfacies types indicate a very shallow, restricted, hypersaline, lagoonal setting periodically exposed to subaerial conditions, which evolved into sabkha sequences. The presence of laminar calcretes fragments, further supports a subaerial continental environment.

Brecciation started soon after deposition, due to periodic seasonal desiccation and small-scale meteoric removal of intrastratal evaporites. Shortly after, a major brecciation event occurred due to progressive dissolution of evaporites, by infiltration of meteoric fluids. During that lowstand episodes, that led to an interruption of sedimentation, the breccias have been intensively affected by soil-forming processes.

The brecciated appearance of the studied formation was further accentuated by post-Pliocene to Recent soil-forming processes, that led to the formation of porous carbonate breccias (rauhwackes).

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