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The Permian-Triassic of the Gartnerkofel-1 Core (Carnic Alps, Austria): Mineralogy of the Shaly and Marly Interbeds

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With 2 Text-Figures, 1 Table and 1 Plate

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Carinthia
Carnic Alps
Shale
Marl
Mineralogy
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Zusammenfassung

In der Bohrung Gartnerkofel-1 (Naßfeld, Karnische Alpen, Österreich) bestehen die schiefrigen und mergeligen Zwischenlagen in der oberpermischen Bellerophon-Formation und in der untertriadischen Werfen-Formation hauptsächlich aus Quarz und Glimmer und untergeordnet aus Dolomit und sehr wenig Calzit. Einige Proben enthalten geringe Mengen von Chlorit und eine führt reichlich Pyrit. Für die Werfen-Formation ist eine mehrphasige Dolomitisierung anzunehmen, die in gleicher Weise auch die unterlagernde Bellerophon-Formation erfaßte. Vulkanischer Quarz und Schwermineralspektren belegen eindeutig einen Vulkanismus zur Zeit der Ablagerung der tieferen Teile der Werfen-Formation im ältern Skyth (Griesbach-Stufe). Hingegen fehlt in unserem Material jeder Hinweis, der die Annahme eines katastrophalen (extraterrestrischen) Ereignisses an der Perm/Trias-Grenze rechtfertigen würde.

Abstract

The dolomitic shaly to marly interbeds of the Gartnerkofel I core consist beside dolomite and inferior amounts of calcite mainly of quartz and mica. Some samples contain small amounts of chlorite, and one of them is enriched in pyrite. Microfacial investigation give evidence for a multistage dolomtization for the Werfen beds and a penecontemporaneous one for the Bellerophon Formation. Volcanic quartz and heavy minerals give definite indications of volcanic activity in the basal Werfen Formation. The interbeds give no evidence for a catastrophic extraterrestric event at the Permian/Triassic boundary.

1. Introduction

The Bellerophon and Werfen Formations in the core are mainly dolostone but about shaly to marl interbeds are randomly distributed throughout the section. The interbeds are each a few mm thick, and 45 of them provided enough material for mineralogical analysis. Some samples may be partly mixed with the main dolomite lithology of the core and the results are sometimes limited by small size of samples. The purpose of this study was to characterize these interbeds. The main considerations were:

1) To classify the interbeds according to mineralogical and microfacies points of view.

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Table 1.
Sampling of interbeds for mineralogical analysis.

Unit 4: Campil Member		Unit 3: Mazzin/Seis Members		Unit 2: Tesero Horizon	Unit 1: Bellerophon Formation	
57 m–95/82 m Interval		3 B: 95/82 m Interval – 175 m		224.50–231.3 m	1 B: 231.3–293.5 m	
Sample Nr.	Depth	Sample Nr.	Depth		Sample Nr.	Depth
12	74.40	25	90.30		205	231.04
14	75.90	28	95.25– 95.33		215	237.84
15	76.35	29	95.92		216	240.26
19	81.60	31	97.38– 97.45		232	259.60
		37	103.80		236	263.55
		44	113.20–114		238	266.80
		45	114		239	267.46
		59	134.50		244	272.95
		64	140.60		262	292.30
		74	152.60		1A: 293.5–331 m	
		81 B	163.30		265	294.80
		82	163.88–163.90		284	314.83–314.86
		3A: 175–224.50 m			286	315.48
		89	180.33			
		100	181.50			
		104B	183.27			
		112	184.80			
		117	185.55–185.56			
		118B	185.80			
		122	186.77			
		133	181.50			
		136	189.50			
		160	198.36			
		183	215.35			
		184	215.70			
		186	216.62			
		190	222.20			
		194	222.35			
		196	224.52			

2) To determine whether the interbeds are the result of an increased siliciclastic input, or can they be explained by diagenetic processes?
3) Are the interbeds all of the same origin?

The Gartnerkofel-1 core (Text-Fig. 1) can be divided into 5 units based on stratigraphic, paleontological, microfacies and geochemical criteria. The distribution of our samples is given in Table 1.

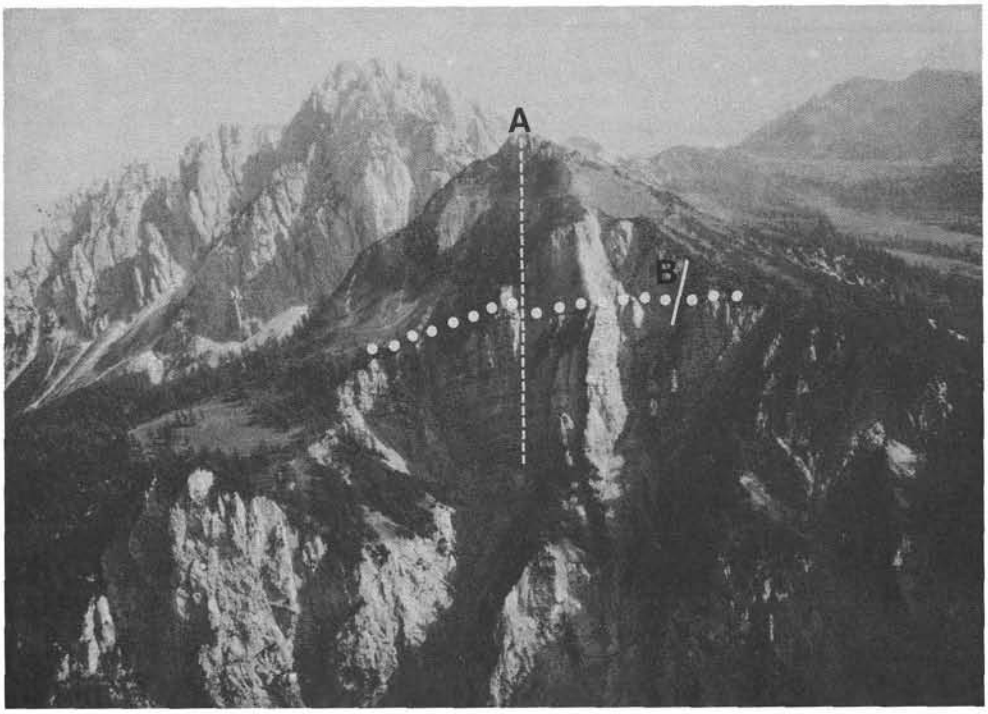
No interbeds occur within the Tesero Horizon; only the base and top layers (Nr. 196 and 205) were investigated.

2. Methods

When sufficient material was available, the following investigations were performed:

1) Microscopy (including fluorescence microscopy [J. J. DRAVIS & D. A. YUREWICZ, 1985] of thin sections.
2) SEM- and EDAX.
3) Insoluble residue (data obtained from P. KLEIN, this volume)
4) XRD (Cu Kα)
   a) of randomly oriented specimes of the total sample
   and
   b) well-oriented samples of the insoluble residue (1 N HCl) sedimented on glass slides.

Where possible the calcite/dolomite-ratio was estimated according to C. B. TENNANT & R. W. BERGER (1957). The stoichiometry was determined by the relationship between calcium content and d(104) spacing (J. R. GOLDSMITH, D. L. GRAF & O. I. JOENSU, 1955; J. R. GOLDSMITH & D. L. GRAF, 1958), using NaCl as internal standard. The frequency distribution of the minerals (Text-Fig. 2) was estimated in following manner: the soluble part by subtracting the insoluble residue was equated with the content of the carbonate minerals (exclusive of pyrite-rich samples because some pyrite is dissolved under the



Text-Fig. 1.
Aerial photograph from the north of the Reppwand with the Gartnerkofel (2195 m) in the background.
A: Drill site on Kammleiten (1998 m);
B: Top of the outcrop section.
Dotted line indicates the Permian–Triassic boundary between the Bellerophon Formation (below) and the Werfen Formation above.
Photo: G. FLAJS, Aachen.

acid treatment). The quartz content was estimated using quartz as an internal standard. A definite amount of quartz was mixed with the sample and the intensity of d (100) spacing of the natural sample was compared with that of the quarz-enriched samples. The content of the other minerals was estimated, using the intensity of the first basal reflection.

5) Heavy minerals (K. STATTEGGER).

3. Mineralogy

The carbonate content (mainly dolomite) of the interbeds varies between 80 % (marl-dolomite) and 0 % (clay) (F. W. BARTH, C. W. CORRENS & P. ESCOLA, 1939) probably in part owing to admixture of neighbouring carbonate rocks. Most of the interbeds are dolomitic marls (5–15 % dolomite). Among the others carbonate-rich samples predominate over clay-rich.

The mineralogical composition of the interbeds is uniform. Beside dolomite and inferiour amounts of calcite the samples consist mainly of quartz and mica. As a general trend the interbeds of Untis 1A and 1B are richer in micas, while in the younger units quartz and mica occur in similar amounts. Some samples are quartz dominated. The interbeds of Unit 4 and the upper parts of Unit 3B contain small amounts of chlorites. Sometimes calcite can be the dominant mineral (sample 184, Unit 3A). In sample 117 (Unit 3A) pyrite is enriched and some gypsum is found in sample 118 B.

Text-Fig. 2, in addition to the mineralogical distribution of the interbeds, also shows some samples of the "pure" dolomites (sample Nrs. underlined in Text-Fig. 2).

Dolomite

Appears in three varieties:

a) Aphanocrystalline, more or less homogeneous dolomites.

b) Closed and open dolomite fabrics (different packing density of dolomite crystals) with eu- to anhedral crystals of finely crystalline to medium crystalline size (R. A. FOLK, 1959). Especially in the units 3A–4 the interbeds are clearly laminated by reason of closed and open fabrics.

c) Dedolomites (calcite) with grains up to 0.4 mm. The dedolomites are zoned and have Ca-rich nuclei and sometimes calcite cores to dolomite rhombs are visible (Unit 4, sample 19). The Ca/Mg ratio varies between Ca_{50}/Mg_{50} and Ca_{52}/Mg_{48}. The interbeds of the Bellerophon Formation are stoichiometric; the Werfen units are nonstoichiometric dolomite with a small Ca-excess. Very small amounts of calcite occur in Units 3B and 4, representing incipient dedolomitization.

Quartz

Detrital silt-sized grains dominate; only in samples 112 (Unit 3A) there are quartz-grains with sizes up to 1 mm. They are of eu- to subhedral shape and show typical resorption vacuoles.

Mica

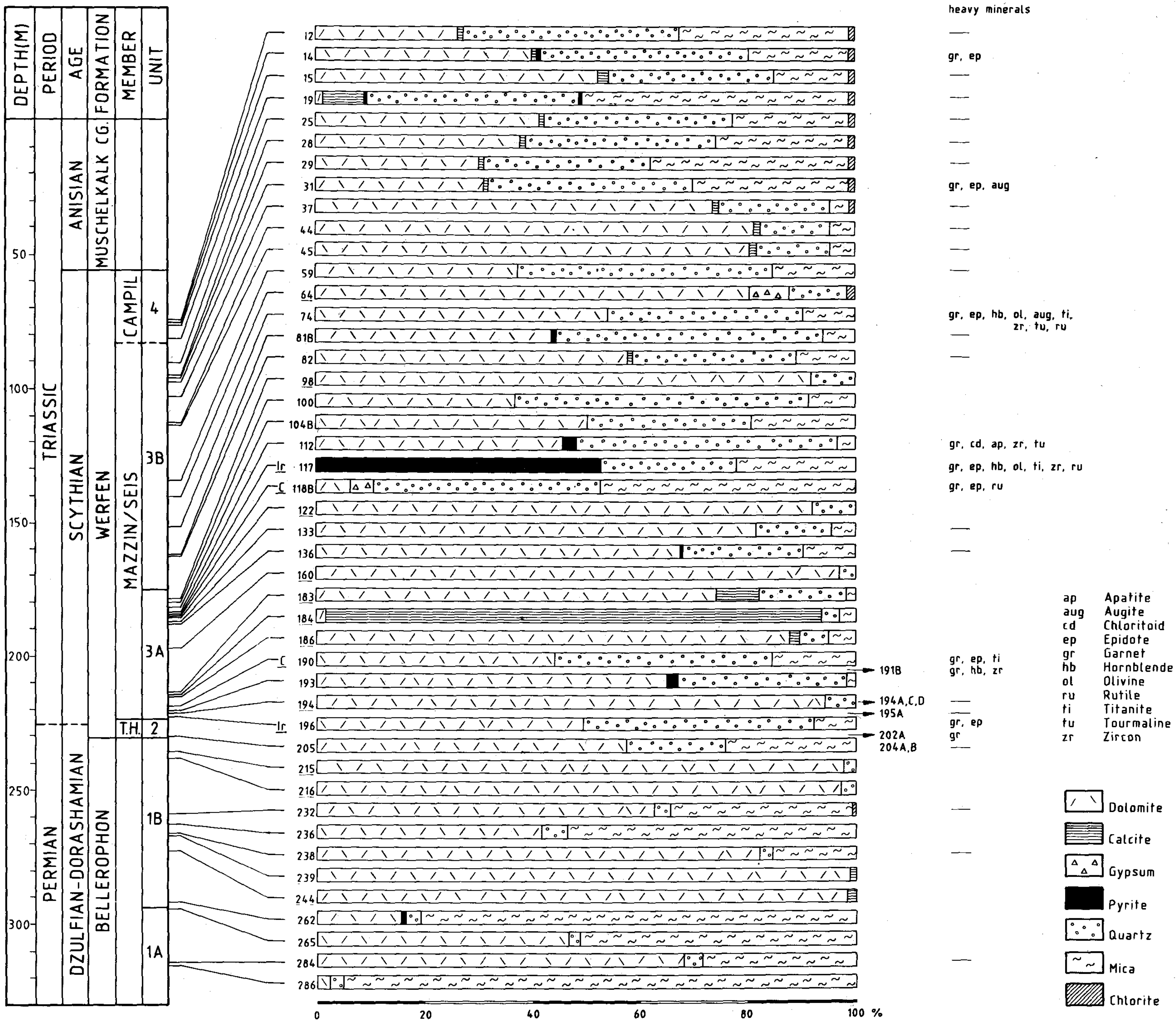
Clay-to silt-sized micas dominate; J.-M. SCHRAMM (this volume) has determinated that these are muscovite of low crystallinity. Numerous micas were investigated by EDAX-analysis: only in Unit B we could find some indications for the existence of biotite.

Chlorite

A small amount of chlorite occurs with the mica in Units 3B and 4 of the Werfen Formation. In the parts of the Bellerophon Formation intersected by the core only one sample (232, in Unit 1B) contained chlorite, although W. BUGGISCH (1974) reported chlorite from the basal Bellerophon (below the cored interval).

Pyrite

Small amounts of pyrite are common throughout the core, as evident in the anaylsis for S and Fe (P. KLEIN, this volume). Only in sample 117 (Unit 3A) was it domi-



Text-Fig. 2.
Mineralogy of the interbeds.

nant in our XRD analysis. Much of the pyrite is framboidal (W. T. H. HOLSER, this volume).

Gypsum

In the interbeds gypsum was found only in sample 118 B (Unit 3A) below the pyrite layer. The sulfate probably originated by ground-water oxidation of the pyrite, as evidenced by equivalent sulfur-isotope ratio (E. PAK, this volume).

Heavy minerals

(K. STATTEGGER)

A few detrital heavy minerals could be identified in 10 samples of the Werfen Formation (Units 2–4); (Text-Fig. 2).

In all samples most are minerals of metamorphic provenance: mainly garnet (gr.) with some epidote (ep) and pale-green hornblende (hb) grains. Of special interest is the occurrence in 3 samples of olivine (ol) and augite (aug) indicating basic magmatic source rocks. Occasionally titanite (ti), apatite (ap), chloritoid (cd) and the stable minerals zircon (zr), tourmaline (tu) and rutile (ru) are found.

4. Microfacies

From a microfacies point of view the samples could be classified into 6 different types:

1) Early diagenetic, mainly aphanocrystalline dolomite marls of the Bellerophon Formation (Units 1 A, 1 B), (Pl. 1, Fig. 1). Some samples show evidence of bioturbation, and flaser structures reinforced by stylolitization ([smooth stylolites of B. W. LOGAN & V. SEMENIUK, 1976]; non-sutured seam solution microstylolites and swarms of H. R. WANLESS [1979]) (Pl. 1, Fig. 2).
2) Laminated dolomite marls. The lamination is mainly of late diagenetic origin and is evident as an alternation of closed and open dolomite fabrics. The origin of this lamination may be a differential susceptibility to dolomitization of layers with differing clay content (Pl. 1, Fig. 3).
3) Late diagenetic dolomite marls with flaser bedding and some evidence of bioturbation. This type is similar to type 1) dolomite crystals, but with larger dolomite crystals.
4) Dolcrete (dolomitic calcrete): Dolcretes and dolcrete nodules of early diagenetic origin appear especially in Unit 1 B. These consist of redeposited dolomite clasts, sometimes encrusted, in marly dolomitic matrix (Pl. 1, Fig. 6).
5) Laminated dolomite marls with laminae of volcanic quartz (Unit 3A, sample 112). Euhedral to subhedral outline, straight extinction and resorption vacuoles are charateristics for volcanic quartz (Pl. 1, Fig. 5).
6) Dedolomites: They occur in Unit 3B as well as in Unit 4. The zoned crystals are cut by stylolites. This means that dedolomitization occurred earlier than stylolitization (J. M. BUDAI et al., 1984), (Pl. 1, Fig. 4).

5. Genetic and Environmental Implications

Certain aspects of the above data might be useful for a general analysis of dolomitization and environmental evolution:

1) The dolomitization of the interbeds is multistage (H. QUING & E. W. MOUNTJOY, 1989). Only the dolomitization of the interbeds of the Bellerophon Formation is interpreted as penecontemporaneous, presumably by evaporitic brines during early exposure.
2) The processes forming the interbeds are heterogeneous. Following mechanics can be considered:
   a) An increase of siliciclastic input, for instance the laminated dolomites with volcanic quartz, or the interbeds of the Bellerophon Formation.
   b) Formation of dolcretes, representing the final stage of a regressive cycle. The existence of dolcretes of the Bellerophon Formation shows that, within a dominant subtidal environment, regressive cycles exist.
   c) Some interbeds show, in addition to burial dolomites, other diagenetic features such as stylolitization. So it is unlikely that the formation of those interbeds is only primary.
   d) Some interbeds might be explained as top layers of tempestite cycles (K. BOECKELMAN, this vol.).
   e) according to K. STATTEGGER a metamorphic provenance of Late Paleozoic clastics from Variscan mountain building has been previously established by heavy mineral data from the Carnic region (W. BUGGISCH, 1978; A. FENNINGER & K. STATTEGGER, 1977; W. SCHNABEL, 1976; G. F. TIETZ, 1975).
   Volcanic quartz (unit 3A, sample 112 = 184.80 m) and heavy minerals give definite indications of volcanic activity in the basal Werfen Formation. Olivine and augite occur in the interval 185.57 to 97.40 m above the P/T boundary (Text-Fig. 2). The persistence of these unstable minerals suggests sedimentation of fresh basic volcanic material in a carbonatic environment, which favored preservation. Basic volcanic rocks are found in the Permo-Scythian Haselgebirge of the Northern Calcareous Alps (E. C. KIRCHNER, 1980).
3) Certain interbeds also show peaks of iridium and other metals (C. J. ORTH et al., this volume), or minima of ^{13}C (M. MAGARITZ & W. T. H. HOLSER, this volume), as marked in Text-Fig. 2 by *Ir* and *C* respectively. With one exception, the mineralogy of these interbeds is very similar to that of other interbeds along the entire core, and none qualify as a "boundary clay" with evidence of fallout from a catastrophic impact or volcanic eruption. However, the most evident difference in mineralogy of the boundary clay at the Cretaceous/Tertiary boundary is an increased content of mixed-layer smectite-illite clay (M. R. RAMPINO & M. C. REYNOLDS, 1983; M. KASTNER et al., 1984), and any such deposit in the Gartnerkofel section would probably have been recrystallized by subsequent diagenesis and anchimetamorphism (J. M. SCHRAMM, this volume).
   The single exception to this uniform mineralogy of all the interbeds is Sample 117 at 185.55–185.56 m (Text-Fig. 2), which differs in its large content of pyrite. The pyrite is diagenetic, much of it is framboidal, a characteristic it shares with some of the boundary clay at the Cretaceous/Tertiary contact (B. SCHMITZ et al., 1988). The pyrite-rich interbed will be discussed in further detail by W. T. H. HOLSER (this volume).

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Plate 1

Fig. 1: **Early diagenetic dolomite marl of the Bellerophon Formation with evidence of bioturbation.**
Unit 1B, Sample 232, ca. 6 ×.

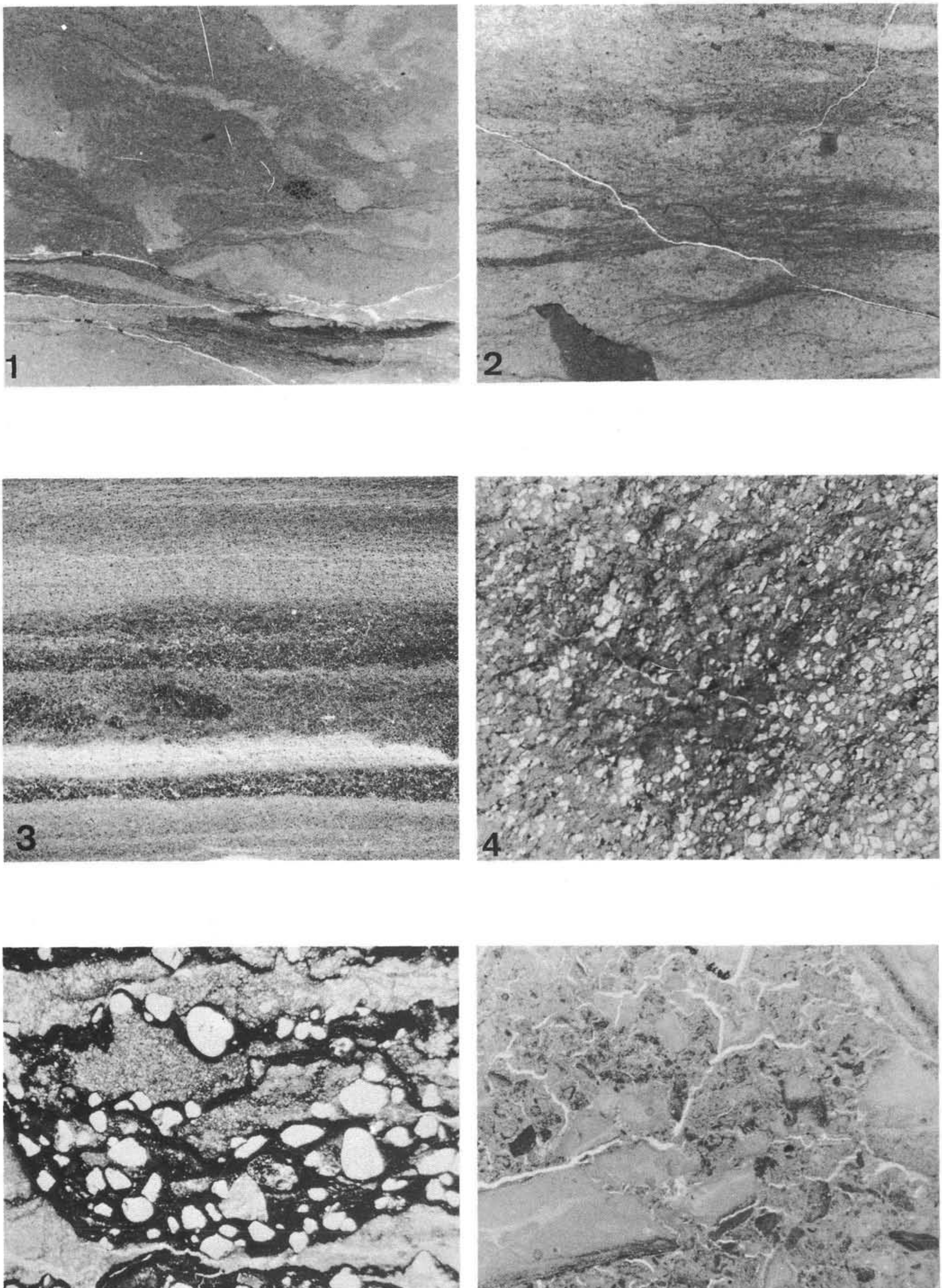
Fig. 2: **Dolomitic marl of the Bellerophon Formation with flaser structures reinforced by stylolitization.**
Unit 1A, Sample 265, ca. 6 ×.

Fig. 3: **Laminated dolomite marl.**
Unit 3B, Sample 37, ca. 6 ×.

Fig. 4: **Dedolomites with Ca-rich nuclei cut by stylolites.**
Unit 4, Sample 19, ca. 6 ×.

Fig. 5: **Lamina of volcanic quartz.**
Unit 3a, Sample 112, ca. 6 ×.

Fig. 6: **Dolcrete.**
Unit 1B, Sample 236, ca. 6 ×.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