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T. J. A. Reijers (*).—DIAGENESIS IN THE REEFAL FACIES OF THE MIDDLE TO UPPER DEVONIAN PORTILLA LIMESTONE FORMATION OF NW SPAIN.

Recent stratigraphical, sedimentological and paleontological studies have added to our knowledge of the Portilla Limestone Formation in the Middle to Upper Devonian of the Cantabrian Mountains in NW Spain (ADRICHEM BOOGAERT 1967, SLEUMER 1969, REIJERS 1969, 1972, 1973, 1974, STRUVE and MOHANTI 1970, MOHANTI 1972). Fig. 1 summarises the main characteristics and the mutual relationships of the depositional facies. For a detailed description reference is made to an earlier publication (REIJERS 1972). It is now felt that a more precise definition is needed of the diagenetic facies.

The author believes that in many instances diagenetic processes, like depositional ones, are diagnostically selective with respect to the physiographic zone in which they act (Fig. 2). Especially early diagenetic processes show a preference to certain diagenetic and depositional environments which are defined by mechanical, physical and chemical properties of the agents. In contrast to depositional environments the criteria needed to differentiate diagenetic environments are only just beginning to establish.

In this contribution an attempt is made to describe diagenetic processes and to relate these, on a time base, to diagenetic environments. It will be shown that certain diagenetic facies (defined as assemblies of diagenetic fabrics which enable us to reconstruct diagenetic processes and environments) characterise certain diagenetic environments. These facies may even characterise physiographic zones if they are result of early diagenetic processes. In order to fulfill the scope of this study, diagenetic fabrics are described, illustrated, analysed and mutually compared. Finally, six lithofacies of the Portilla Limestone Formation are individually described as the final overprint of depositional and diagenetic processes acting on the same sediment.

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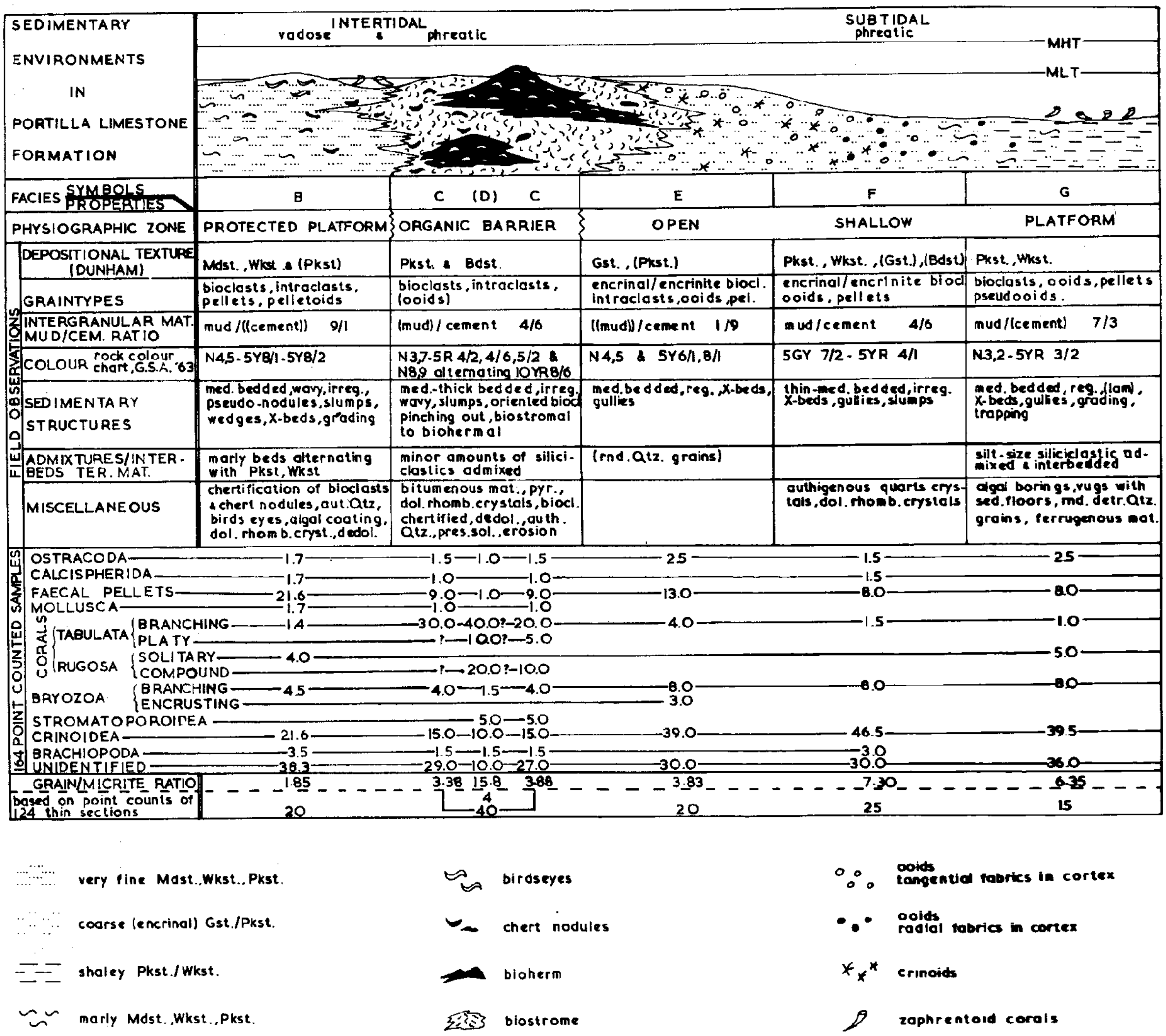

	FACIES SYMBOLS / PROPERTIES	B	C (D) C	E	F	G
	PHYSIOGRAPHIC ZONE	PROTECTED PLATFORM	ORGANIC BARRIER	OPEN	SHALLOW	PLATFORM
FIELD OBSERVATIONS	DEPOSITIONAL TEXTURE (DUNHAM)	Mdst.,Wkst. & (Pkst)	Pkst. & Bdst.	Gst., (Pkst.)	Pkst., Wkst., (Gst.), (Bdst)	Pkst.,Wkst.
	GRAINTYPES	bioclasts, intraclasts, pellets, pelletoids	bioclasts, intraclasts, (ooids)	encrinal/encrinite biocl. intraclasts, ooids, pel.	encrinal/encrinite biocl. ooids, pellets	bioclasts, ooids, pellets pseudooids.
	INTERGRANULAR MAT. MUD/CEM. RATIO	mud/((cement)) 9/1	(mud)/cement 4/6	((mud))/cement 1/9	mud/cement 4/6	mud/(cement) 7/3
	COLOUR rock colour chart, G.S.A. '63	N4,5-5YB/1-5Y8/2	N3,7-5R 4/2, 4/6, 5/2 & N8,9 alternating 10YR8/6	N4,5 & 5Y6/1,8/1	5GY 7/2-5YR 4/1	N3,2-5YR 3/2
	SEDIMENTARY STRUCTURES	med. bedded, wavy, irreg., pseudo-nodules, slumps, wedges, X-beds, grading	med.-thick bedded, irreg., wavy, slumps, oriented biocl. pinching out, biostromal to biohermal	med. bedded, reg., X-beds, gullies	thin-med. bedded, irreg. X-beds, gullies, slumps	med. bedded, reg., (lam), X-beds, gullies, grading, trapping
	ADMIXTURES/INTERBEDS TER. MAT.	marly beds alternating with Pkst, Wkst	minor amounts of siliciclastics admixed	(rnd. Qtz. grains)		silt-size siliciclastic admixed & interbedded
	MISCELLANEOUS	chertification of bioclasts & chert nodules, aut. Qtz, birds eyes, algal coating, dol. rhomb. cryst., dedol.	bitumenous mat., pyr., dol. rhomb. crystals, biocl. chertified, dedol., auth. Qtz., pres. sol., erosion		authigenous quarts crystals, dol. rhomb. crystals	algal borings, vugs with sed. floors, rnd. detr. Qtz. grains, ferrugenous mat.
164 POINT COUNTED SAMPLES	OSTRACODA	1.7	1.5—1.0—1.5	2.5	1.5	2.5
	CALCISPHERIDA	1.7	1.0—1.0		1.5	
	FAECAL PELLETS	21.6	9.0—1.0—9.0	13.0	8.0	8.0
	MOLLUSCA	1.7	1.0—1.0			
	CORALS TABULATA BRANCHING	1.4	30.0-40.0?-20.0	4.0	1.5	1.0
	CORALS TABULATA PLATY		?—10.0?—5.0			
	CORALS RUGOSA SOLITARY	4.0				5.0
	CORALS RUGOSA COMPOUND		?→20.0?–10.0			
	BRYOZOA BRANCHING	4.5	4.0—1.5—4.0	8.0	6.0	8.0
	BRYOZOA ENCRUSTING			3.0		
	STROMATOPOROIDEA		5.0—5.0			
	CRINOIDEA	21.6	15.0—10.0—15.0	39.0	46.5	39.5
	BRACHIOPODA	3.5	1.5—1.5—1.5		3.0	
	UNIDENTIFIED	38.3	29.0—10.0—27.0	30.0	30.0	36.0
	GRAIN/MICRITE RATIO	1.85	3.38 15.8 3.88	3.83	7.30	6.35
	based on point counts of 124 thin sections	20	4 40	20	25	15

Fig. 1.— Sedimentary environments and their properties for the Portilla Limestone Formation (compare also REIJERS, 1972).

DIAGENESIS; SUBDIVISION AND CHARACTERISTIC PROCESSES

The field of diagenesis impinges on the fields of sedimentation, weathering and metamorphism. The depositional, weathering, and metamorphism interfaces form the three boundaries of diagenesis (Fig. 3). Strict definition of these boundaries is less important than clear recognition of individual substages. Therefore, these substages will now be discussed in terms of characteristic processes and their products.

The field of diagenesis includes syndepositional, precementation, cementation and postcementation substages. The syndepositional and precementation substages can be regarded as comprising the syngenetic stage, which roughly corresponds with NAGTEGAAL'S (1967) «interval of early and advanced diagenesis», and with FAIRBRIDGE'S (1967) «interval of syndiagenesis». The syngenetic stage is predated by a predepositional stage in which physico-chemical conditions are those of erosion and transport.

—In the SYNDEPOSITIONAL SUBSTAGE do the physico-chemical conditions of the physiographic zone (e. g. water temperature, Eh, pH) define the diagenetic envi-

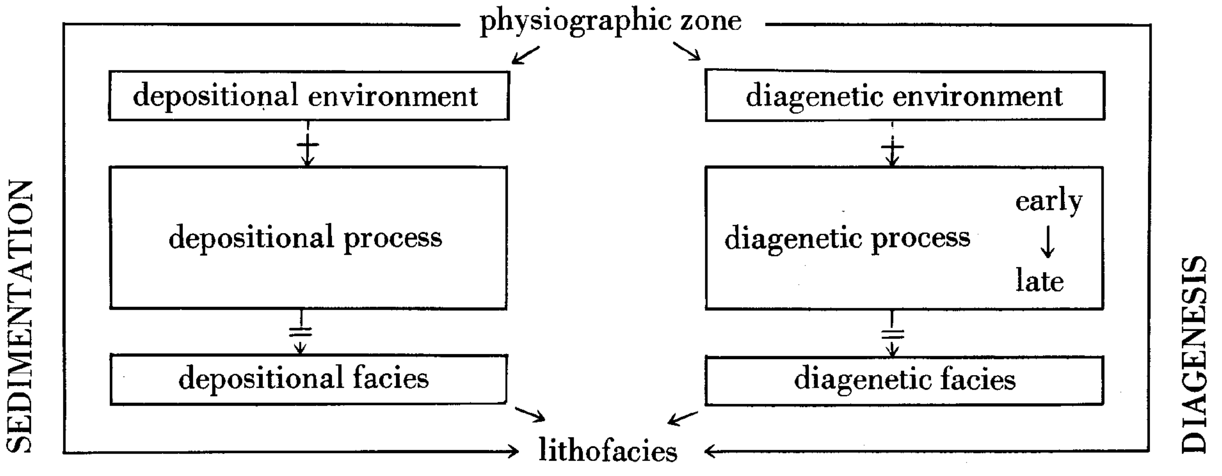

Fig. 2.— Terminology used in present paper.

ronments. They also directly control the diagenetic processes. Three processes characterise this substage in the Portilla Limestone Formation: silicification of corals and stromatoporoids, authigenesis of ferruginous material and bioturbation. The last one will not be discussed in detail.

(i) Silicification of corals and stromatoporoids.— Great quantities of chert are present in depositional facies C and D and smaller quantities in depositional facies B and F (Fig. 1). In certain intervals moderate to severe silicification of entire or fragmented corals and stromatoporoids occur (Fig. 4). The following questions are posed. Is this silicification an early or a late diagenetic process? Where does the silica come from? Why is silicification mainly confined to reef tract and back reef environment? Why are corals and stromatoporoids preferentially silicified?

The restriction of chert to certain depositional facies only, and to well defined horizons herein, is regarded as an indication for transportation of silica into the basin of deposition during sedimentation. Most of the silica was trapped behind the reef tract, explaining the areal preference of chert for depositional facies B, C and D. Only a small amount spilled into the fore-reef environment where it settled on the moderately energetic platform margin during periods of complete submergence of the reefs (cf. Reijers, 1974). The transportation and settling of silica was mainly governed by hydrodynamic and physico-chemical factors.

Erosional zones in bioherms continue in a lateral sense into chert-layers in back reef deposits (cf. Fig. 1, and Reijers 1972, 1974). This additional evidence supports the hypothesis that silica was brought into the basin during sedimentation because it suggests that transport of silica towards the open sea was prevented during emergence of bioherms, and silica was forced to settle behind, and in, the reefs. Silicification is therefore regarded as a syndepositional process.

The author has no direct knowledge and knows of no description of either desert environments or of volcanic activity in the Middle-Upper Devonian in NW Spain. Therefore he regards it unlikely that silica in the Portilla Limestone Formation was derived from desert dust or from volcanic glasses. The complete absence in silica and

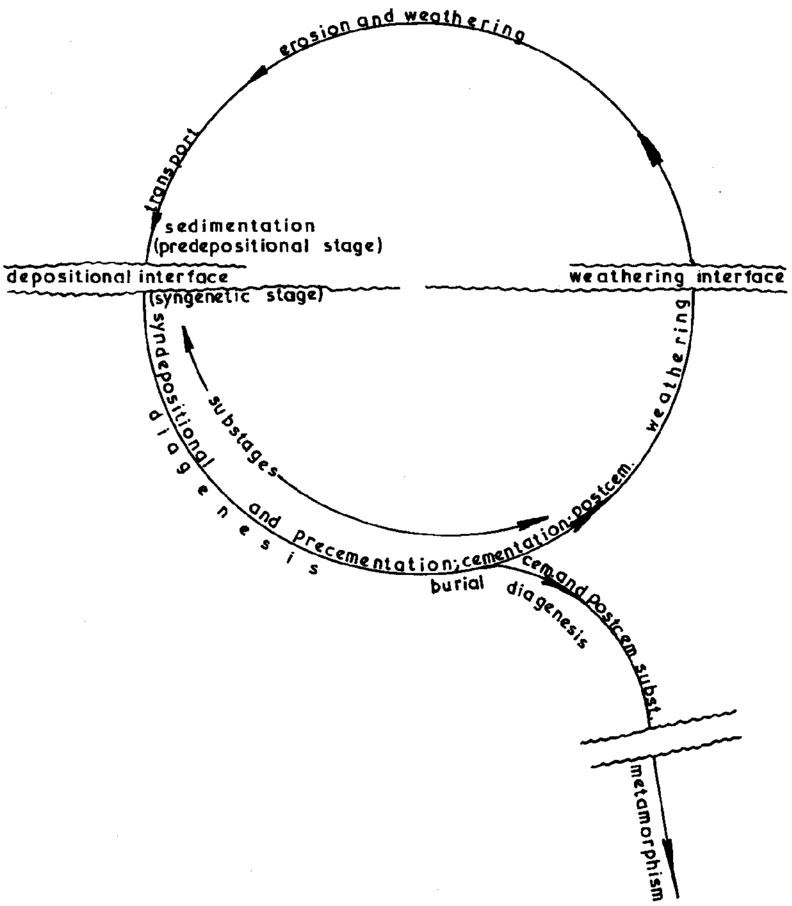

Fig. 3.—Lithogenetic cycle picturing the relations between sedimentation, diagenesis and metamorphism. Diagenesis is subdivided into stages and substages.

in carbonates of traces of organisms with siliceous skeletons such as radiolaria, diatoms or sponge spiculae rules out an organic origin. The most likely source of the silica is therefore a deeply weathered hinterland (cf. Adrichem Boogaert 1967, and Reijers 1972, 1974). Presumably the silica was transported as a gel (cf. Erhart 1956, 1963). Support for this assumption is found in the clotty and irregular appearance of the chert, and in the extremely fine, unoriented crystalline substructure of silica under the polarising microscope. In the process of stabilising silica gels and transforming them into chert, coagulation is the next step.

Coagulation, according to Krauskopf (1959) is triggered by a low pH-value. Microenvironments in which pH-values are low, were apparently abundantly present in the back-reef and reef tract where decaying organic material reduces the pH-value. Such microenvironments are encountered in small cavities like latilaminae and holes in coenostea of stromatoporoids (cf. Sleumer 1969, p. 24) and in corallites of ramose and platy tabulate corals (Fig. 4). Because corals and stromatoporoids are present in abundance in the Portilla Limestone Formation, there was plenty of scope for the coagulation of silica gels.

Numerous intraformational discontinuities in depositional facies C and D and some in depositional facies B (Reijers 1974) indicate periods of emergence. During these periods silica could dehydrate under evaporitic conditions, as suggested by the presence of length-slow chalcedony (cf. Folk and Pittman, 1971).