SEDIMENTARY MECHANISMS IN SPANISH DEVONIAN CARBONATES[1]

T. J. A. REIJERS[2]

ABSTRACT

Reijers, T. J. A. 1980 Sedimentary mechanisms in Spanish Devonian carbonates – Geol. Mijnbouw 59: 87-96.

In the Middle-Late Devonian Santa Lucía and Portilla Formations in the Cantabrian Mountains (NW Spain), a series of facies belts parallels the palaeo-coastline. They represent from N to S a back-barrier, barrier and fore-barrier setting. Mild sea-level changes and epeirogenetic movements governed the rate and mode of carbonate production and controlled movements of these facies belts basinwards and marginwards.

Carbonate masses in which such sedimentary movements are reflected can be correctly mapped regionally only if the interval is subdivided into units, each representing one movement. On a more local scale, carbonate masses reflect the same sedimentary mechanisms in the internal organization of carbonate build-ups.

INTRODUCTION

The occurrence of an almost complete succession of well-exposed Palaeozoic strata on the southern slope of the Cantabrian Mountains (NW Spain, province of Léon, see Fig. 1) has stimulated a number of detailed studies of the Middle-Late Devonian carbonates (e.g. DE COO ET AL., 1971; REIJERS, 1972, 1973, 1974 - a, b; MOHANTI, 1972; DE COO, 1974; MÉNDEZ-BEDIA, 1976). These studies demonstrate the presence of a series of facies belts parallelling the palaeo-coastline (the Asturian geanticline of DE SITTER, 1962) and representing supra/intertidal, back-barrier and barrier facies in the case of the Santa Lucía (Fig. 2) and back-reef, reef and fore-reef facies in the case of the Portilla Formation (Figs. 3, 4) from north to south. A late Devonian unconformity progressively truncates and removes the succession towards the north (Fig. 5) so that the younger reefoid facies in the Givetian-Frasnian Portilla Formation can be studied towards the middle and southern parts of the basin and the highest studiable back-reef facies is the Emsian-Couvinian Santa Lucía Formation in the north of the basin. Nevertheless, there is sufficient overlap in space and in similarity of facies characteristics for reconstruction and correlation of the basic lateral and vertical sedimentation patterns and processes (Figs. 6, 7). This reconstruction is the object of the present note.

SEA-LEVEL CHANGES: FIRST-ORDER CYCLICITY

As is widely known, sedimentary carbonate accumulation is essentially controlled by two factors: the rate of carbonate production (predominantly organic skeletal carbonate) and relative sea-level changes. Carbonate production is optimal in tropical, shallow, euphotic, well aerated, high-energy environments. The rate can be in or out of balance with sea-level movements so that the carbonate masses grow in step with sea-level rise or build out (prograde) when the production rate exceeds the sea-level rise. However, when the sea-level rise is too fast, the carbonates either drown out or grade back with the transgression. In the Cantabrian Mountains the carbonate masses were able to build out over certain time intervals, whereas over other time intervals they were less successful and were forced back by the rising sea-level.

[1] Manuscript received: 1979-07-15.
Revised manuscript received and accepted: 1979-10-30.

[2] Shell Expro UEE/9, Shell-Mex House, Strand, LONDON WC-2, Great Britain.

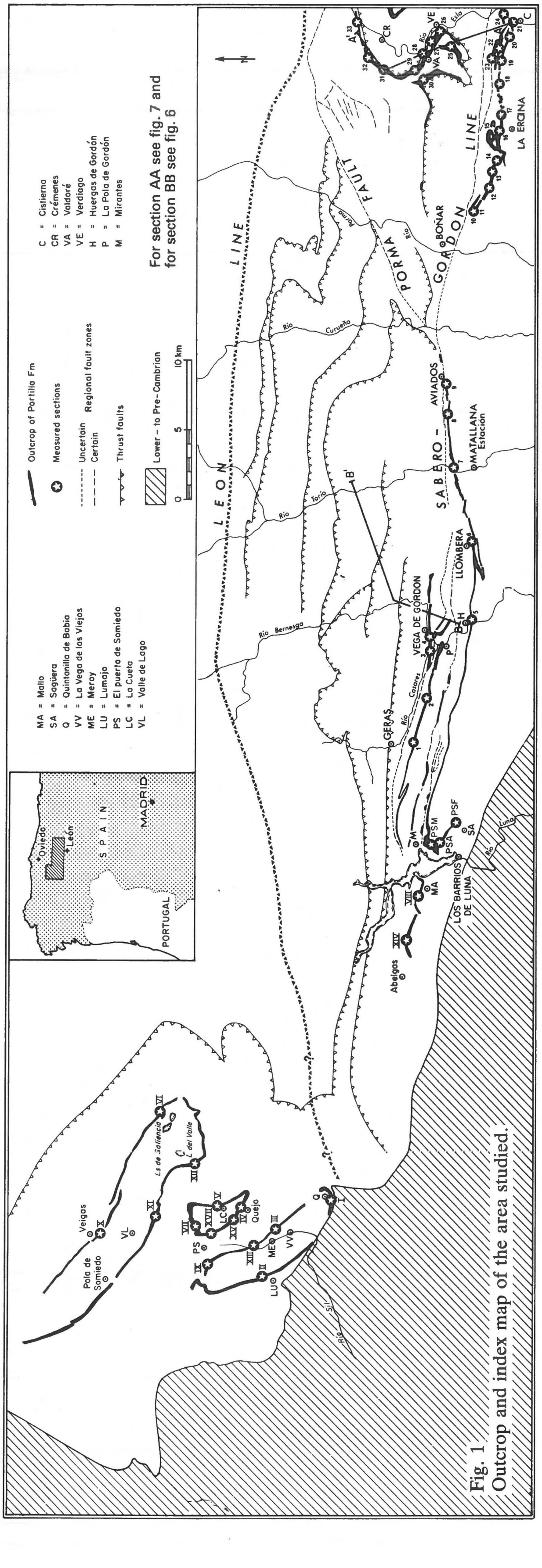

Fig. 1
Outcrop and index map of the area studied.

Moreover, owing to synsedimentary bottom movements (REIJERS, 1974-a), building up occurred locally in a narrow zone around the Sabero-Gordón fault zone.

REIJERS (1974-a) argued that epeirogenetic movements were the major controlling factor concerning sedimentary variation in the Late Devonian. In the more stable blocks between the major, structurally active trends a first-order cyclicity in the sequence is formed by pulses of clastics, breaking the continuity of carbonate sedimentation (Fig. 5). These correlatable clastic units are supposed to result from periods of reactivation of the hinterland supply areas.

SECOND-ORDER CYCLICITY

It is also possible to recognize a finer, second-order cyclic subdivision within the carbonates. This is reflected by characteristic vertical lithofacies sequences (Figs. 6, 7) or internal zonation in build-ups (Fig. 8).

The vertical sequence is an expression of the existence of three facies belts (Figs. 2, 3). From N to S these are a back barrier belt; a reef track (in the Portilla Formation) or a belt with grainstone bars (in the Santa Lucía Formation); and a fore-barrier belt. With a moving substrate or with sea-level changes, the optimum position of these belts shifts with respect to the coastline. This constitutes vertical cyclicity.

In a lateral sense the shallow-marine sediments of the Santa Lucía and Portilla Formations show gradual changes in environmental parameters from north to south such as:

(1) a trend from restricted to more normal marine conditions, shown by an increase in faunal diversity, particularly by growth forms of corals and stromatoporoids characterizing the reef zone. Crinoids, bryozoans and brachiopods indicate the fore-reef zone (Figs. 2, 4). The more restricted faunal elements (ostracods and molluscs) gradually disappear.

(2) evidence of high hydraulic-energy increases southwards, culminating in high-energy sediments such as grainstones, framestones, bindstones and boundstones (EMBRY & KLOVAN, 1972) forming the reef track.

(3) back-reef and reef track evidence very shallow waters but pass to moderately deep marine in the fore-reef facies, evidenced by the disappearance of mud cracks, birds'-eyes, faecel pellets and dedolomistisation zones, and by appearance of slightly nodular, argillaceous limestones with brachiopods and crinoids.

Reef masses that accumulated in the narrow zone of fault activity do not follow the mechanism discussed above, but reflect changing environmental conditions in a characteristic internal architecture. As an example one reef is shown diagrammetically (Fig. 8).

In the last few years several investigators have tried to relate environmental conditions to organic growth forms and species abundance. For reefs, one of the most successful models has been proposed by ALBERSTADT ET AL. (1974). With

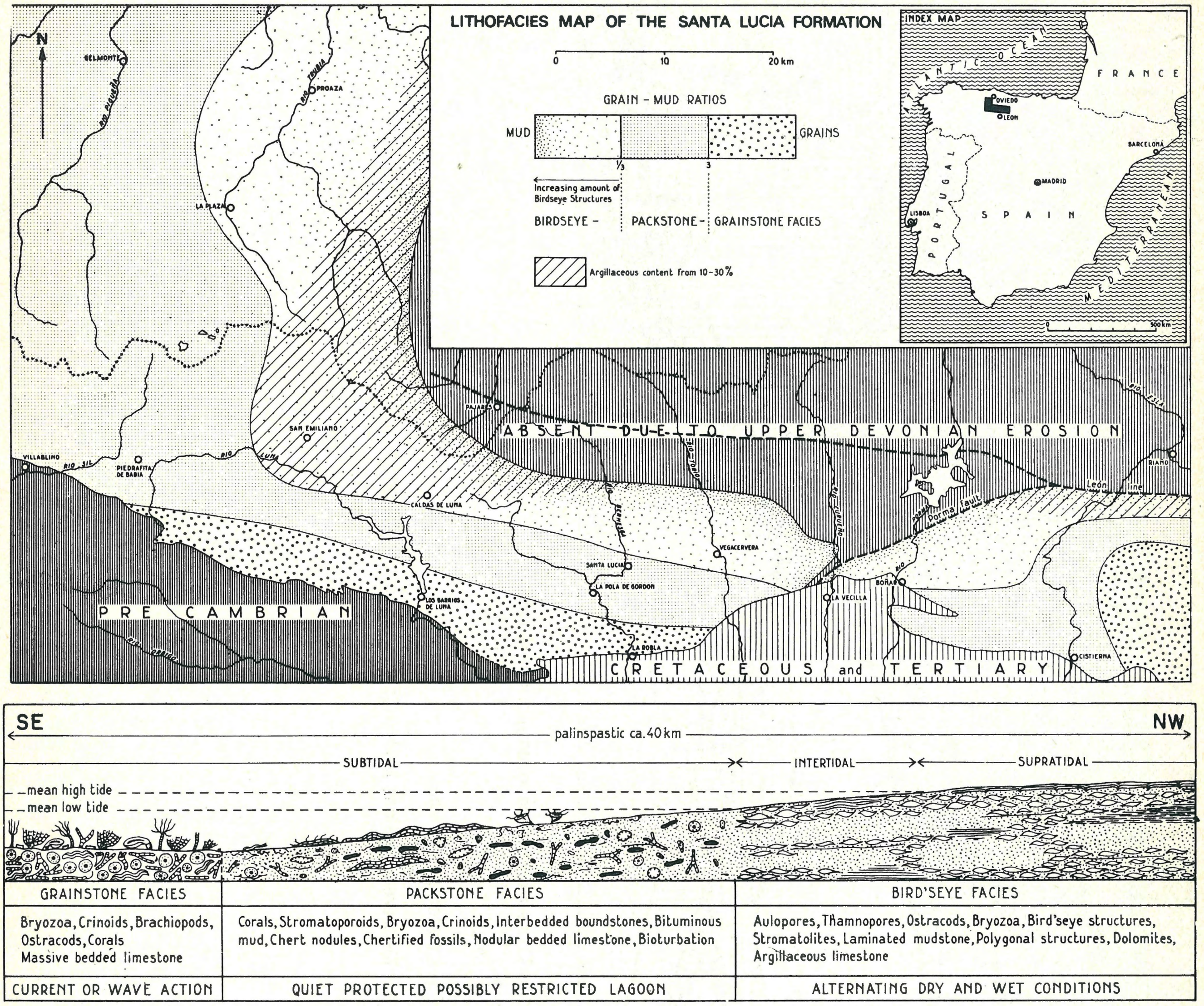

Fig. 2
Sedimentation model of the Santa Lucía Formation (from: De Coo et al., 1971).

the aid of this model an environmental interpretation can be attempted from a vertical fauna zonation in a reef. The model recognizes four stages in the growth of a build-up: those of establishment of the faunal components, colonization, diversification and domination. These stages successively reflect the following shallow-marine environmental conditions: open circulation and moderate hydraulic energy, followed by gradual shallowing until optimum hydraulic conditions in shallow-marine, well-aerated and insolated water are reached.

These stages have all been recognized in the reef N. of Cistierna (Fig. 8). Independently of the vertical facies sequences elsewhere, they also indicate the existence of a cyclic sedimentation mechanism that brings the substrate in alternating positions, more or less optimal for reef building organisms.

FACIES PATTERNS

Upward building of carbonates results from an equilibrium between carbonate-production rate and sea-level rise. In the Cantabrian Mountains this equilibrium occurred during the Devonian in a narrow zone, allowing development of bioherms up to 30 m high, with a lateral spread up to 400 m (Figs. 8, 9). The facies composition of the various carbonate intervals follows a general pattern (see example in Fig. 8), but in detail it may be variable, reflecting response to specific environmental changes.

The common bioherm development in the Portilla Formation is seemingly related to synsedimentary movements in the narrow bioherm zone which acted as a major hinge line parallelling the basin margin (Figs. 9, 10). Such movements apparently did not occur during deposition of the older Santa

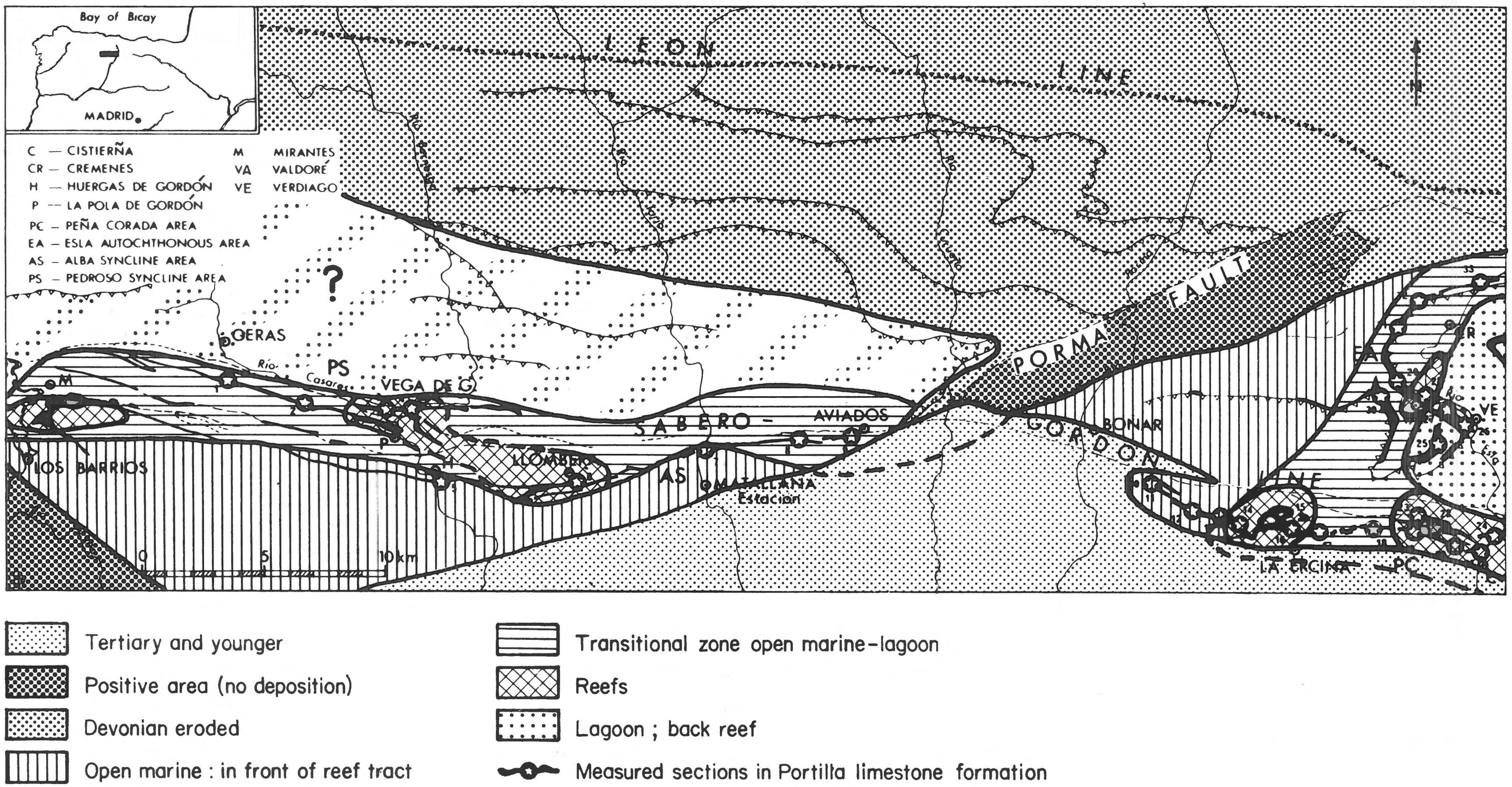

Fig. 3
Lithofacies map of the Portilla Formation.

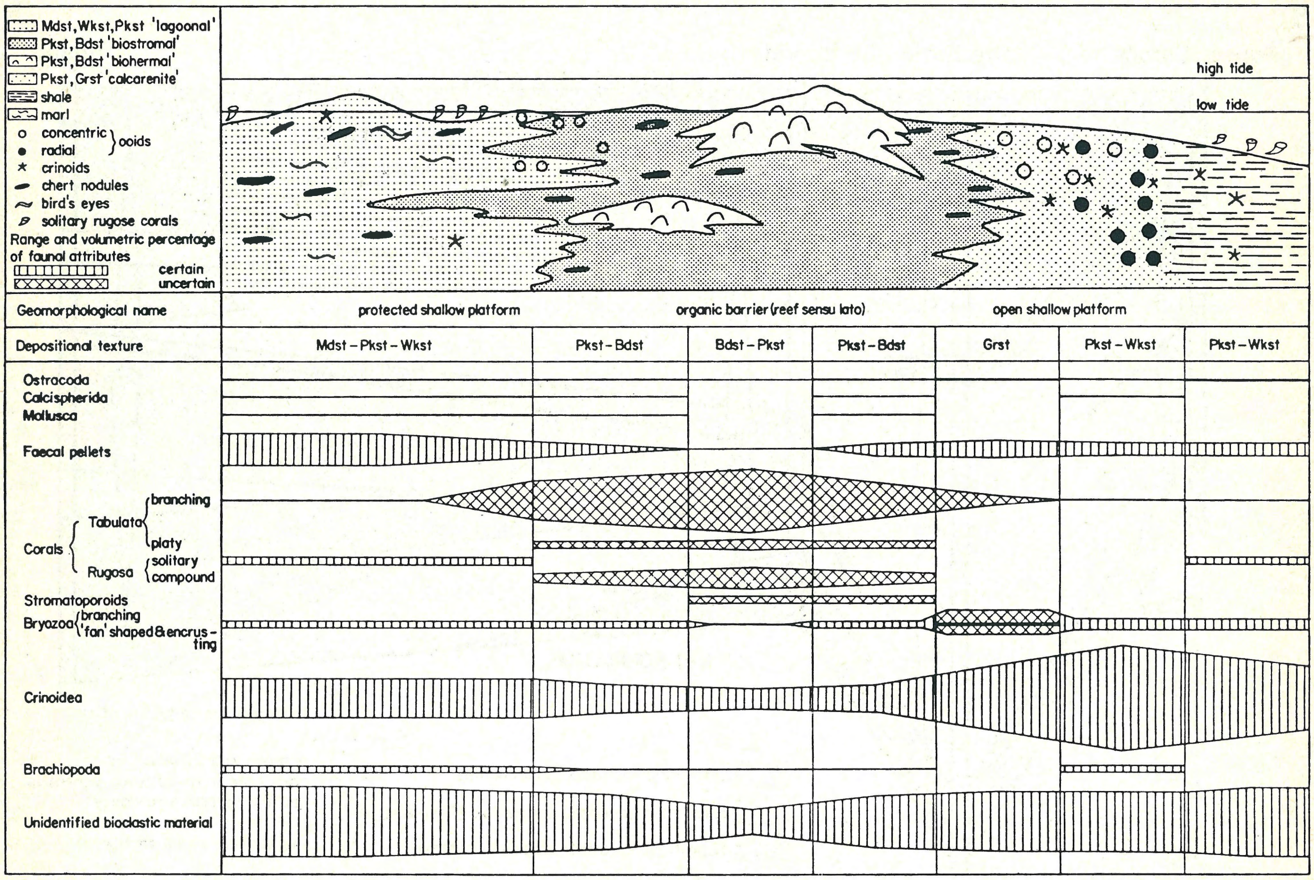

Fig. 4
Sedimentation model of the Portilla Formation.

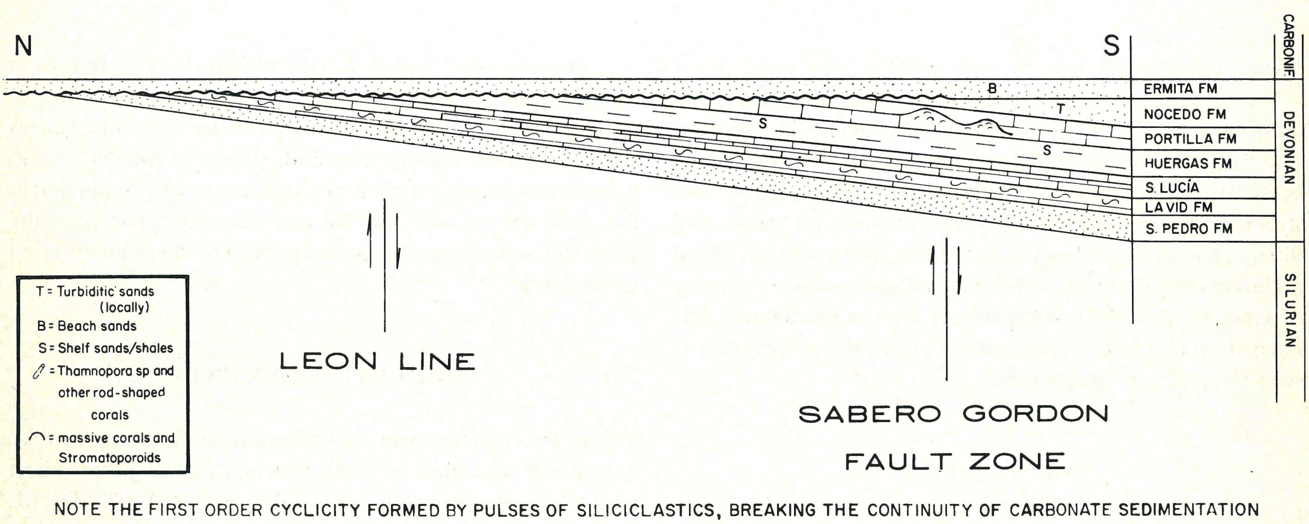

Fig. 5
Generalized N-S cross-section, showing the Late Devonian unconformity truncating the Devonian succession progressively towards the North (not to scale).

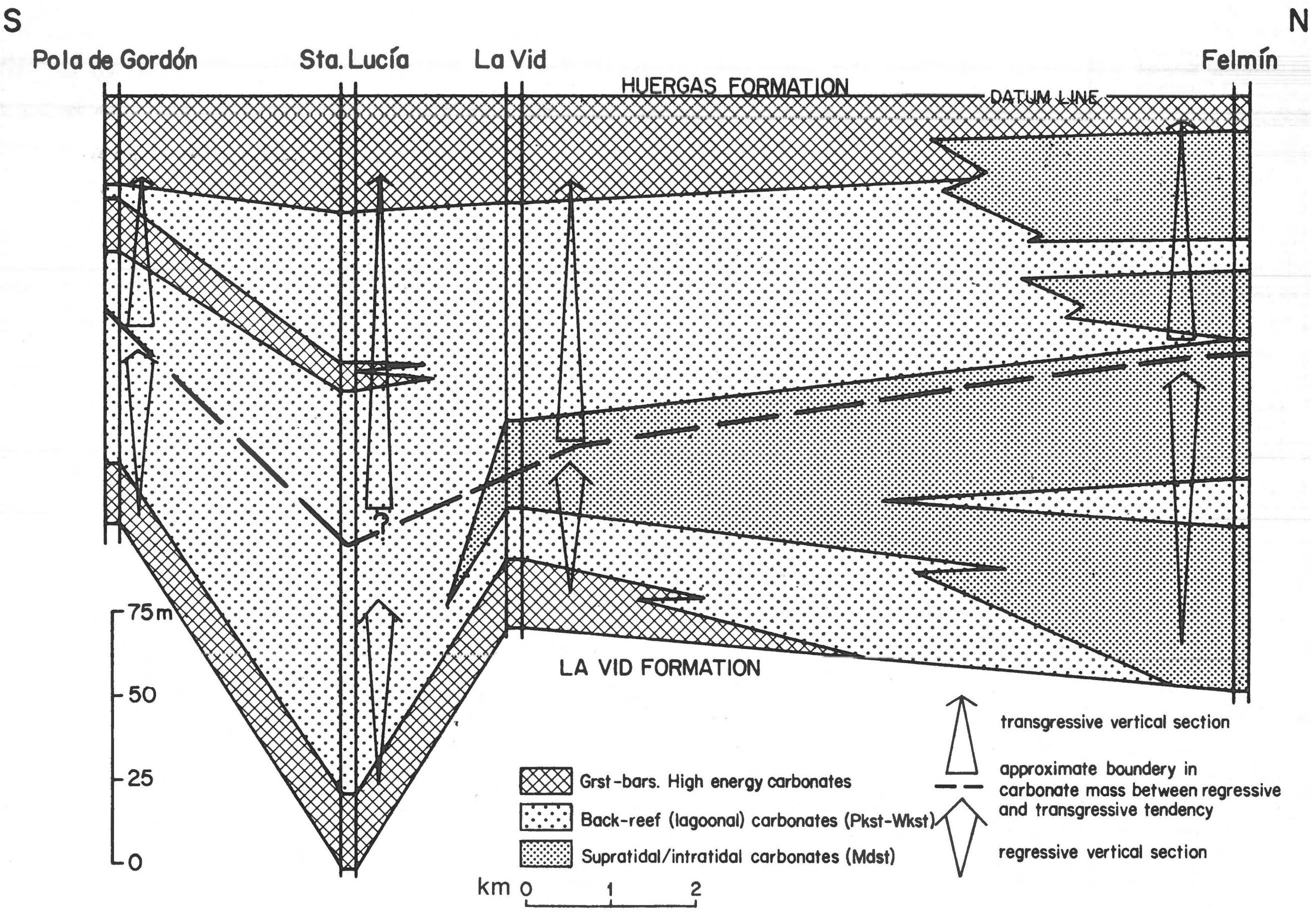

Fig. 6
Sedimentation patterns in the Santa Lucía Formation (simplified after De Coo, 1974).

Lucía Formation; hence, no such bioherm belt developed.

The southern and northern parts of the basin subsided at different rates. In the more actively subsiding southern part, slumping occurred at the steepening margins (Fig. 11). In the northern parts, thick accumulations of *Thamnopora* biostromes occurred close to the hinge line and reef tract, and discontinuously over large areas of the back-reef zone. Mud accumulation in the back reef was sufficient so that evidence of sedimentary fill to emergence is seen in the Santa Lucía Formation (Figs. 2, 6); the zone of packstone patch 'reefs' is seen to prograde basinwards.

MAPPABILITY

It is clear that simple facies patterns in the gross interval considered occur only in equilibrium situations. With fluctuating imbalance between sedimentation and subsidence, the reef and associated belts build out or grade back, forming the second-order cyclicity. In such situations it is necessary to subdivide the interval into these subcycles for proper facies study. Statistical mapping methods (maps on which the ratio between fore-reef to back-reef sediments is shown) applied to the gross interval will blur the true patterns apparent in the subcycles and obscure the actual picture of the sedimentation mechanisms.

ACKNOWLEDGEMENTS

This note benefited from discussions in the field between the author and several of his Shell colleagues during three short trips to the province of León in 1976, 1978 and 1979. Dr. M. W. Hughes-Clarke read the text and improved it considerably. The author is grateful to Shell Research B.V. for permission to publish this paper.

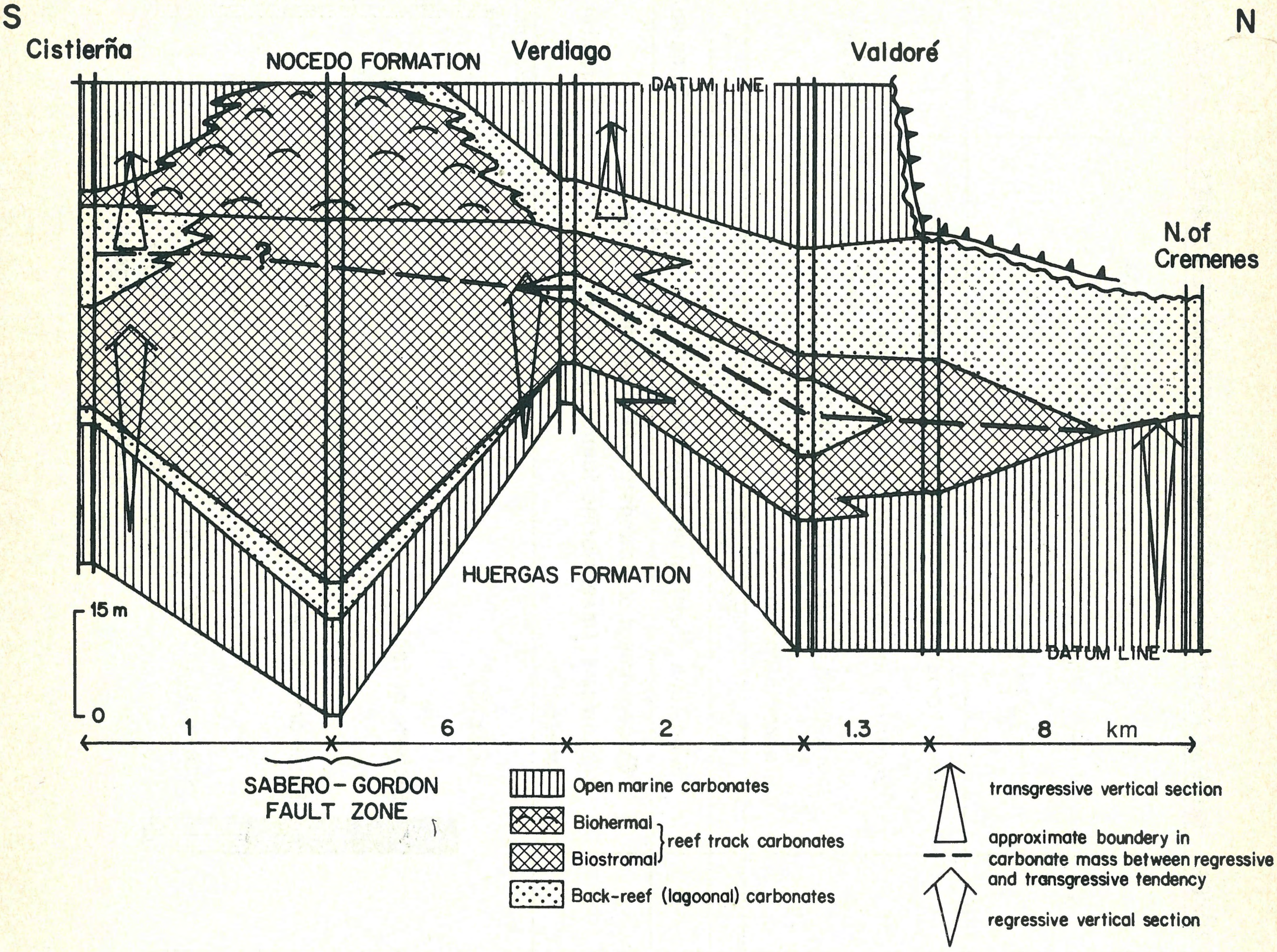

Fig. 7
Sedimentation patterns in the Portilla Formation (simplified after Reijers, 1972).

REFERENCES

Alberstadt, L. P., K. R. Walker & R. P. Zurawski 1974 Patch reef in the Carters Limestone (Middle Ordovician) in Tennessee and vertical zonetion in Ordovician reef – Geol. Soc. Amer. Bull. 85:1171-1182.

De Coo, J. C. M. 1974 Lithostratigraphy of the Devonian Sta. Lucía Limestone in León, Spain – Ph. D. Thesis Univ. Leiden: 87 pp.

De Coo, J. C. M., J. C. Deelman & D. van der Baan 1971 Carbonate facies of the Sta. Lucía Formation (Emsian-Couvinian) in León and Asturia, Spain – Geol, Mijnbouw 50:359-366

De Sitter, L. U. 1962 The structure of the southern slope of the Cantabrian Mountains; explanation of a geological map with sections, scale 1:100.000 – Leidse Geol, Meded. 26:255-264.

Embry, A. F. & E. J. Klovan 1972 Absolute water depth limits of Late Devonian paleoecological zones – Geol. Rschd. 61 (2).

Méndez-Bedia, J. 1976 Biofacies y litofacies de la Formacion Moniello-Santa Lucía (Devonico de la Cordillera Cantabrica NW de España) – Trabajos Geol. Univ. Oviedo 9: 93 pp.

Mohanti, M. 1972 The Portilla Formation (Middle Devonian) of the Alba syncline, Cantabrian Mountains, Prov. León, NW Spain. Carbonate facies and rhynchonellid palaeontology – Leidse Geol. Meded. 48: 135-205.

Reijers, T. J. A. 1972 Facies and diagenesis of the Devonian Portilla Limestone Formation between the river Esla and the embalse de la Lune, Cantabrian Mountains, Spain – Leidse Geol. Meded. 47: 163-249.

—— 1973 Stratigraphy, sedimentology and palaeogeography of Eifelian, Givetian and Frasnian strata between the river Porma and the Embalse de La Luna, Cantabrian Mountains, Spain – Geol. Mijnbouw 52: 115-124.

—— 1974-a Hinge movements influencing deposition during the Upper Devonian in the Esla area of the Cantabrian Mountains, Spain – Geol. Mijnbouw 53: 13-21.

—— 1974-b Diagenesis in the reefal facies of the Middle to Upper Devonian Portilla Limestone Formation of NW Spain – Brev. Geol. Asturica 18: 33-48.

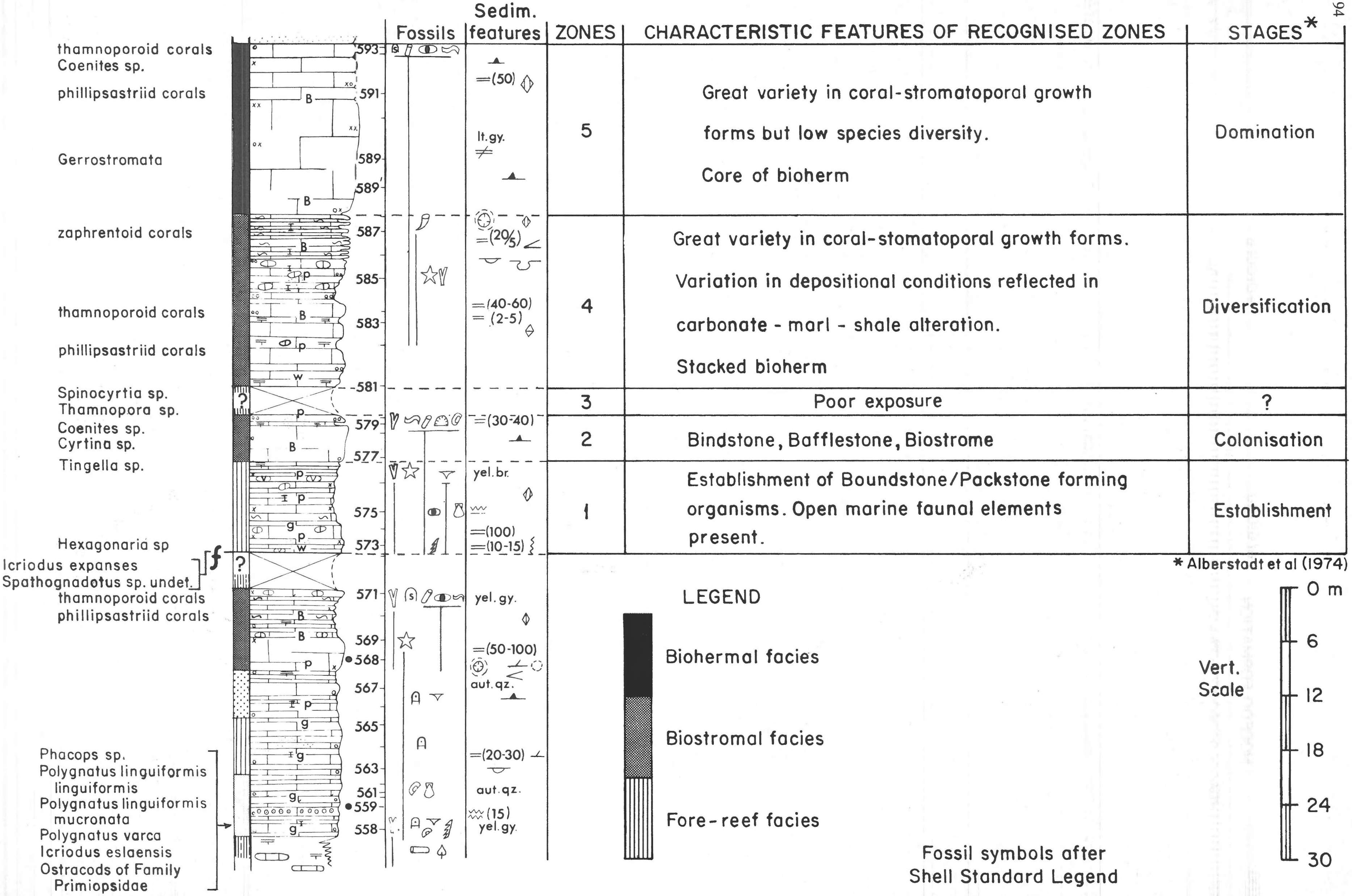

Fig. 8
Second-order cyclicity characteristics in a bioherm, 2 km N of Cistierna.

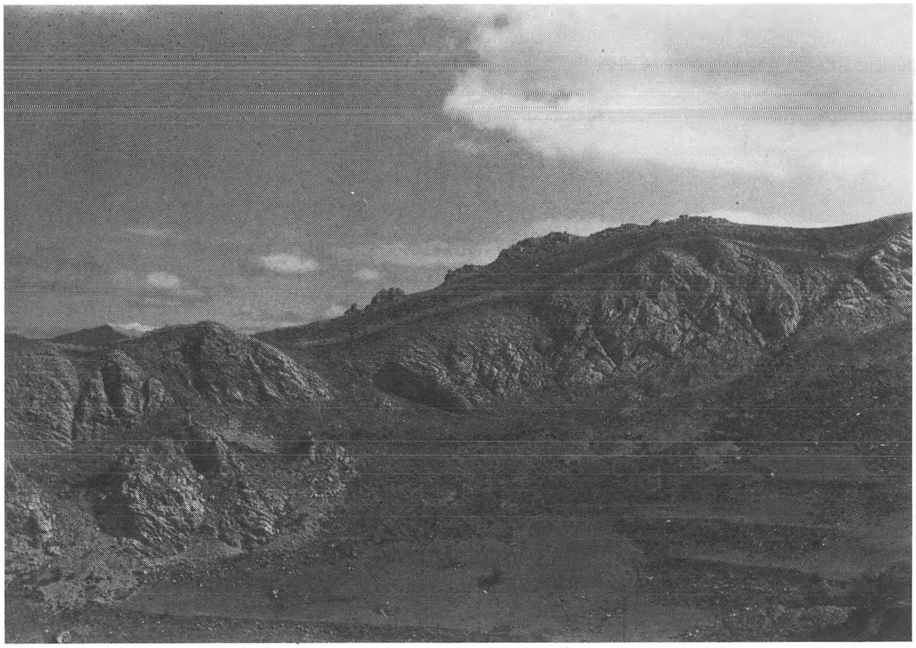

Fig. 9
Bioherms and draping of biostromes N of Cistierna. The reefoid sediments are related to the Sabero-Gordón Fault that runs N of (= behind) this complex. View to the north.

Fig. 10
Reefoid masses N of Cistierna. Note that they parallel the Sabero-Gordón fault zone that splits here into a branch running N of (= behind) this complex and one S of (= before) this complex. View to the NW.

Fig. 11
Slumps in the Portilla Fm. near Sagüera (E of los Barrios de Luna, Fig. 1). This part of the basin is situated south of the Sabero-Gordón Fault zone where more active subsidence locally resulted in slumping, elsewhere in very thick building-up of reefoid masses.