Windsorian Stage (Middle Carboniferous), Antigonish Basin

PAUL E. SCHENK
Department of Geology, Dalhousie University, Halifax, Nova Scotia

GENERAL SETTING

A. GEOGRAPHICAL

At the time of the Middle Devonian Acadian orogeny, Nova Scotia must have been located at the middle of a megacontinent - Africa-Europe-North America (see Schenk's Regional Synthesis, this volume). To the north, the Paleozoic Atlantic must have been closed; to the south, a narrow, but shrinking seaway must have existed until the Late Carboniferous-Permian Allegheny orogeny. During the Carboniferous closing, the eastward bulge of Atlantic Canada made the area into a wrenching crush-zone of fault-block basins and ranges. Perhaps this special "treatment" to this part of the Atlantic provinces more strongly welded the Meguma into North America. In the Early Mesozoic, Atlantic Canada became a triple junction of the North American, African, and European plates. Paleomagnetists place Nova Scotia at 10 degrees south latitude (Irving 1964).

B. ENVIRONMENTAL

The Carboniferous environment was strongly controlled by the geographical setting - equatorial and in a continental interior. Local aridity is indicated by occurrences of thick evaporite lithosomes, the ubiquitous redbeds (low groundwater table), and carbonates with both restricted and dwarf fauna. In the Late Carboniferous, coal swamps indicate more humid, less saline conditions; however, arid or semi-arid climate returned in the Permo-Triassic. During the Carboniferous, a number of horsts served as sources for alluvial fan deposition in intervening linear basins (Fig. 1). The fill is locally at least 13 km thick and is mainly red, non-marine siliclastics. The Middle Carboniferous Windsor Group (Fig. 2) is a kilometre-thick lithostratigraphic unit distinguished by perhaps a dozen cycles, each of marine carbonate and overlying evaporite within the redbeds. The redbeds coarsen to a conglomerate texture toward faulted basin margins marked in places with basaltic

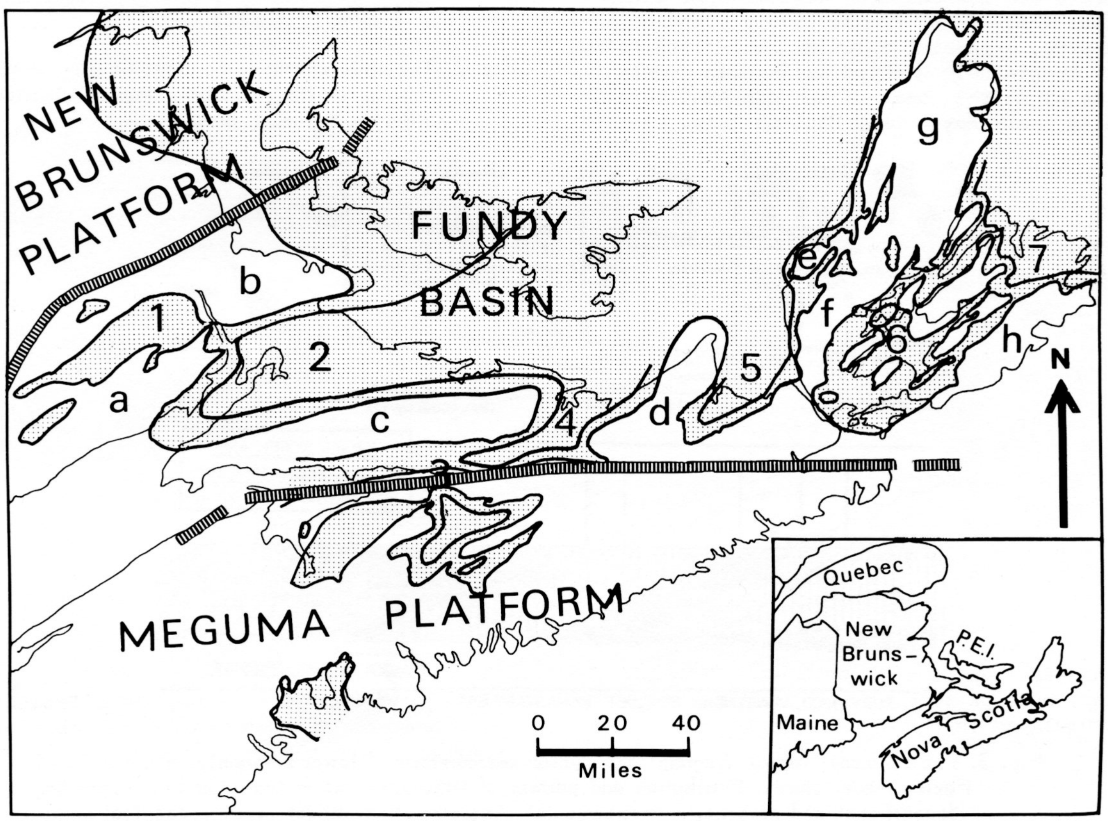


Fig. 1. Present-day, tectonic basins (numbered) of the Windsor Group were at least in part depositional basins during the Windsorian Stage. Intervening horsts (lettered) of Avalon Platform blocks supplied alluvium to basins. Horst "d" is the Pictou-Antigonish Highlands; basin "5" is the Antigonish Basin.

lava (Wilkie Brook, Stop 2). Figure 3 shows the laterial variation in both lithotopes and diagenesis across the Antigonish basin, as revealed by detailed study of vertical sections.

C. MODERN ANALOGUES

Sedimentary successions identical to the Windsor Group are forming today in several well-known areas. The settings are in hot, dry, hostile places where fault-block control leads to alluvial fan deposition by ephemeral streams, to restricted circulation in shallow marine tongues, and to a scarcity of either animal or plant life.

Be thankful that Nova Scotia today is at a wet, cold latitude (halfway to the North Pole!), surrounded by an extensive, if foggy, ocean, and populated by extensive forests, and sufficient people!

One marvelous analogue is the Red Sea, specifically the Afar triangle. The Persian Gulf is a second strong candidate. There, collision between the Arabian and Irani plates is closing the Gulf, restricting marine circulation, and so promoting aridity. On the southwest side, carbonate and evaporite are now building Windsor-type authigenic suites (Purser and Evans, 1975). On the northeast side, extensive alluvial salt-flats fringe the Zagros Mountains. A third well-known modern analogue is along the coast of Western Australia, specifically Shark Bay - Lake MacLeod (Fig. 4).

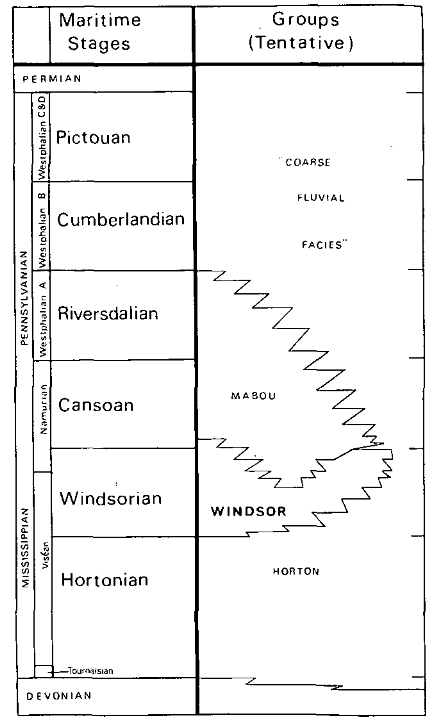


Fig. 2. Tentative stratigraphic classification of the Carboniferous in Nova Scotia. Note distinction between litho-stratigraphic terms.

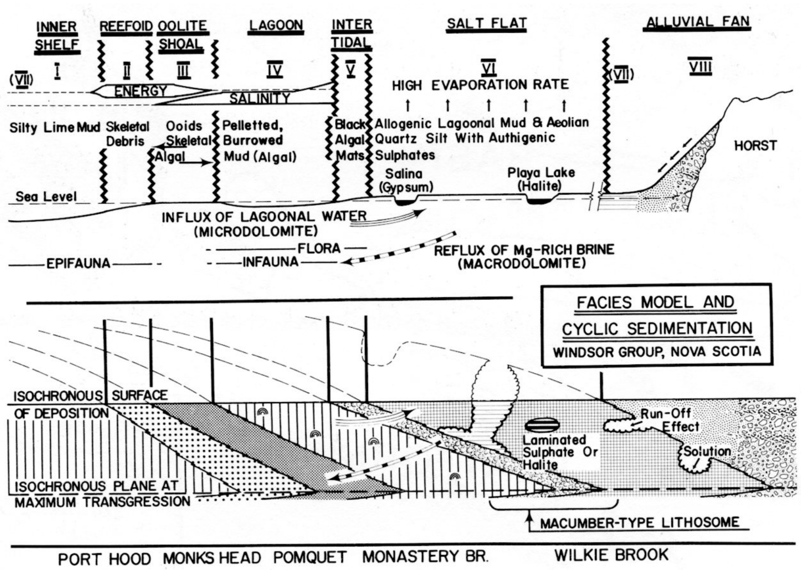


Fig. 3. Facies model (upper diagram) and cyclic sedimentation (lower diagram)of Windsor Group. Facies model shows distribution and pattern of lithotopes and biotopes, and corresponding depositional and diagenetic environmental characteristics. Model gives conceptual picture of paleoenvironment at any instant of time during marine regression; transgression would show lesser development of salt flat. Lower diagram of cyclic sedimentation shows lithosome-biosome relations and patterns beneath depositional surface (upper diagram), here represented by "isochronous surface of deposition". Dashed projections above this surface show subsequent, basinal migration of lithosomes during regression. Run-off by streams carrying terrigenous detritus would dissolve much evaporite, leading to lensy shape (predeformation) of gypsum masses and frequent thin redbed between carbonate and sulfate. Vertical scale much exaggerated. Section localities give mainly offlap sequences, most basinal at Port Hood (Cape Breton Island), marginal at Wilkie Brook (Stop 10).

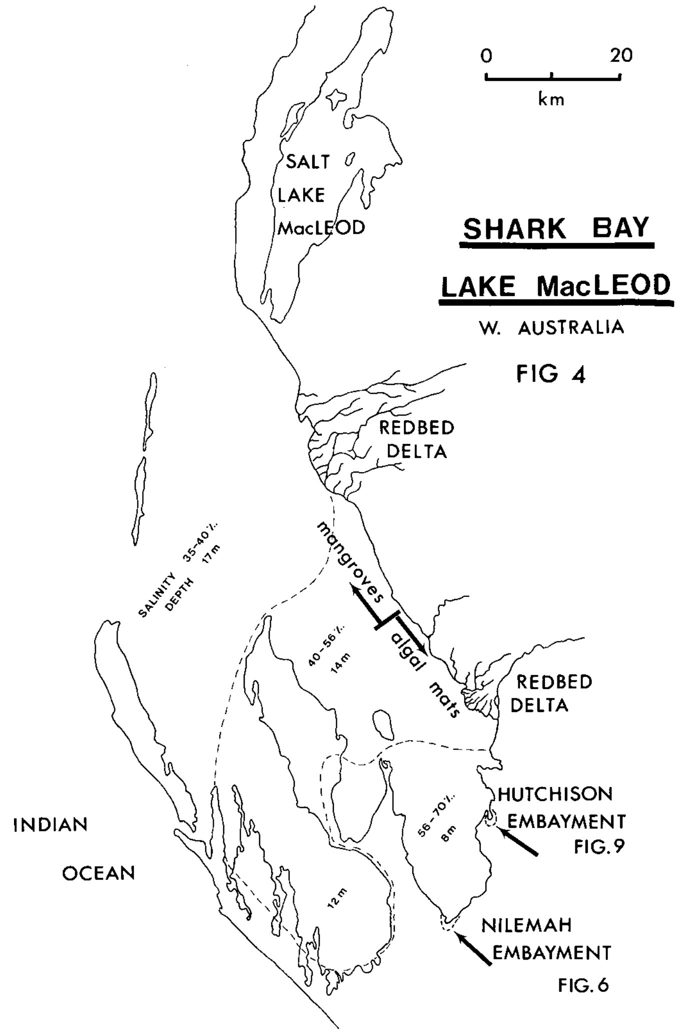


Fig. 4. Geographic map of Sharks Bay - Lake MacLeod area, Western Australia, to show carbonate, chloride, and redbed lithotopes, and flora biotopes reflecting increase in salinity.

Shark Bay - Lake MacLeod is truly a marvelous time-machine back into the Carboniferous - building our blankets of carbonate/sulfate, our fat lenses of chloride, our complexes of redbed alluvium, and perhaps even our precious coal. Figures 5 through 8 show that the major lithotopes of the Windsor are easily walked upon in this carefully studied area (Logan *et al.* 1974). Specific areas such as Nilemah (Fig. 5) and Hutchison Embayments (Fig. 8) are especially fine. In western Australia, a broad, shallow sheet of progressively more saline water extends into a semi-arid hinterland. Fauna are restricted in variety, dwarfed in size, and lead to a profusion of shore-line algal stromatolites. Repeated Pleistocene cycles of redbeds, carbonate, diagenetic gypsum and again redbeds are identical to cycles in the Windsorian. Glacial eustasy is responsible for the former, and perhaps also for the latter, cyclothems. Geographically, the Shark Bay area shows a time sequence of increasing salinity from marginal evaporites (Fig. 5) to closing lagoons and basinal evaporites (salinas) (Fig. 8) and ultimately to giant halite + salinas (Lake MacLeod, see Fig. 4) with precipitated salt at least 60 metres deep. Lake MacLeod is the future for Hamelin Pool. Immense volumes of red siliclastics are swept by ephemeral streams into this carbonate belt (Fig. 4). Late Carboniferous coal in Nouveau Maroc* may also be interpreted in the light of Shark Bay.

Schenk (1969) speculated that during the famous "mid-Carboniferous continental drift-episode" in which Nova Scotia shifted suddenly some 1450 km northeastward, we moved from arid to humid climatic belts. A simpler hypothesis is seen in Figure 4. Northward along the coast, the decrease in salinity promotes more abundantly both herbivores, which eat the intertidal algal mats, and less tolerant coastal mangroves. That is, mangrove swamps replace the carbonate algal stromatolites where salinities decrease; however, the Carboniferous swamps were presumably fresh water.

FACIES MODEL

A. A PRIMER IN CHRONOSTRATIGRAPHY

Windsor outcrops are usually limited to one or two carbonate or carbonate-sulphate strata. The most common carbonate is a laminated limestone to dolostone, called here the Macumber-type (Fig. 9). This unit is very distinctive, easily mapped, and conventionally designated as the base of the stratigraphic section. Unfortunately workers have confused physical position with age so that the Macumber-type is still called, erroneously, the earliest Windsorian carbonate. Patently, lithology reflects environment, not time, unless that environment is a unique event. The environment of the Macumber-type was intertidal, and most common during the repeated floodings and withdrawals of the sea. Moreover, close inspection of the upper parts of almost all Windsorian carbonates displays this intertidal lithosome, although textures and structures of the algal stromatolite vary both with position in the tidal zone and energy level.

* Nouveau Maroc = Nova Scotia (ed.)

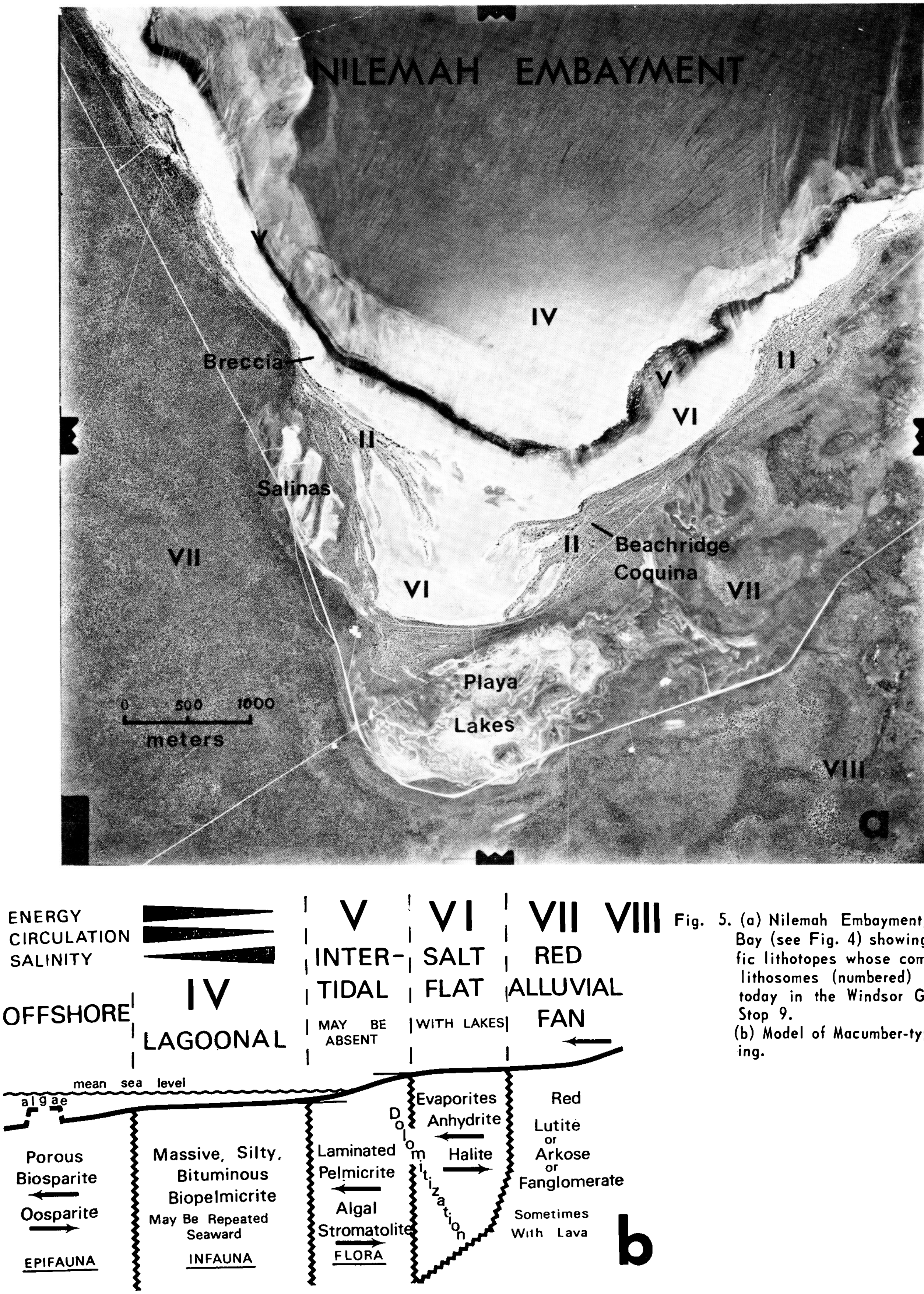


Fig. 5. (a) Nilemah Embayment, Shark Bay (see Fig. 4) showing specific lithotopes whose comparable lithosomes (numbered) we see today in the Windsor Group at Stop 9.
(b) Model of Macumber-type setting.

Figure 10 shows cross-section through the Antigonish basin, in which several wedges of carbonate record marine transgressions, which here are progressively more extensive through time. At any geographic locality, the basal carbonate may be Macumber-type, but all such lithologies are not of the same blanket, or of the same age. Consider this diagram now in plan view. The distal ends (Macumber-type) of successive carbonates, would now crop out individually within a belt along the basin margin. Isolated outcrops of Macumber-type rock, but of many ages, would have similar structural attitudes. In the poor exposure in the Carboniferous basins, lithostratigraphic units (as the Macumber Formation) may be easily drawn but promote incorrect paleogeography for prospectors, and also incorrect structural analysis (Fig. 10).

B. INTRODUCTION OF MODEL

The following account of model development is condensed from Schenk (1969). Eight specific lithosomes (facies) classify the rather orderly vertical succession of each Windsor carbonate. These lithosomes record at any instant of time a lateral succession of lithotopes, each parallel with the shoreline. One must remember that the model is only a model, that variations exist most commonly, and that these variations are the most interesting for details of paleogeography. Such a combination of omissions and repetitions are due to topographic irregularities and inherent characteristics of the lithotope. Topographic irregularities should telescope the model, narrowing some lithotopes, widening others. Along the shoreline, algal stromatolite structures will change from flat features (protected bays - Figs. 5, 9 b-d) to clubs or rows (headlands - Fig. 6 b-e). Local run-off or erosion will prevent full development or preservation of more soluble and/or subaerial parts of the model. Inherent characteristics of the lithotopes would include lateral discontinuity of algal stromatolites, limited extent of salinas or playa lakes, linear and discontinuous form of beach-ridge coquinas (Fig. 5), or lensy shape of ooid shoals.

Facies I

Facies I, the relatively fossiliferous, bituminous, lime biomicrite was deposited in a low energy, poorly aerated zone seaward of the adjacent, high-energy belt. Large brachiopods, crinoids, and echinoids dominate the fauna. Reworking of bottom muds into pellets, coupled with a general lack of stratification, suggests an extensive infauna. The variety and abundance of fauna suggest that waters had near-normal salinity. This, with the abundance of micrite and absence of algal stromatolites, indicates that water depths were at least below surf-base and the most effective zone of photosynthesis. The fragmentation of skeletal debris might be due to scavengers or predators, or possibly transportation of shells broken in the adjacent, high-energy zone landward. The shale interstratified with the carbonate of this facies attests to quiet-water deposition of terrigenous detritus probably carried across landward lithotopes through surge channels. Much of the quartz silt may be wind-blown. Dolomitization of this facies is seldom complete and then only where the carbonate lithosome is thin. The mechanism for this secondary dolomitization will be considered under Facies II and III.

A dark grey, calcareous shale commonly underlies carbonate strata and overlies redbeds. The upper contact is often intercalated with thin lenses of poorly fossiliferous micrite; the lower contact is flat and sharp, where texture changes, or cuspate where grain size is uniform. Brachiopods are rare in this grey shale, but ostracods are numerous. This lithology is added to Facies I but may include the effects of rapid flooding over alluvial flats. In Figure 11, this facies is called VI.

Facies II and III

Facies II and III (biosparite and oosparite respectively) mark the highly turbulent zone upon which most of the energy of the area was expended. Variable directions of cross-stratification and ripple marks suggest a water-depth well within surf-base. Small biohermal centres served as source areas for skeletal debris, washed mainly landward and onto ooid-forming shoals. Such centres were populated mainly by small brachiopods, bryozoans, algae, and rare corals. probably the general environment was a complex assemblage of barrier bars, tidal channels, and oolite deltas similar to those along the Trucial Coast of the Persian Gulf (Purser and Evans, 1973).

The cementing of the ooids is very interesting. Sparry dolomite fills interstices between grains that are commonly coated with a thin, sparry, calcite sheath. Presumably, when the ooids finally came to rest, incipient cementation by calcite, especially around grain contacts, formed a fairly competent but extremely porous and permeable rock mass. Subsequently, dolomite precipitated in grain interstitices, presumably from magnesium-rich brines. Possibly such brines evolved farther landward by evaporation of interstitial sea water and *in situ* precipitation of calcium sulfate. The high magnesium/calcium, dense brine refluxed seaward and precipitated dolomite in the interstitices of first the oolite, and then less efficiently, the biosparite. Biomicrite of Facies I is usually not dolomitized, perhaps due to both the sediments' low permeabity, and to exhaustion/mixing of the relatively high-magnesium brine.

Facies IV

Facies IV, a sparsely fossiliferous, massive, dolomitic biomicrite, was deposited in a low-energy, poorly aerated zone landward of the adjacent high-energy belt. This particular environment is difficult to distinguish from adjacent supratidal areas because the lagoon is the major source from which storms and high tides moved carbonate material into the intertidal and supratidal environments. Pelletted, extensively burrowed, lime mud accumulated in very shallow, quiet lagoons. Occasionally ooids were washed into the lagoons from adjacent shoals; small oncolites and pseudo-ooids were formed near the shore line; flaky clasts of algal mats were washed in from the intertidal-low supratidal environment. The water was very shallow, warm, and highly saline. The fauna, generally consisting of many individuals but very few species were mainly gastropods, tolerant ostracods, and a rich concentration of blue-green algal colonies.

Windsor carbonates are principally off-lap units that record fillings of such lagoons, probably both by prograding and active deposition of aragonite within the lagoon. Such lagoonal aragonite was dolomitized conceivably during early diagenesis when the lagoonal sediments formed part of the supratidal mud flats. Production of finely microcrystalline to cryptocrystalline, microdolomite dolostones or calcitic dolostones of the Windsor Group is described later under Facies VI.

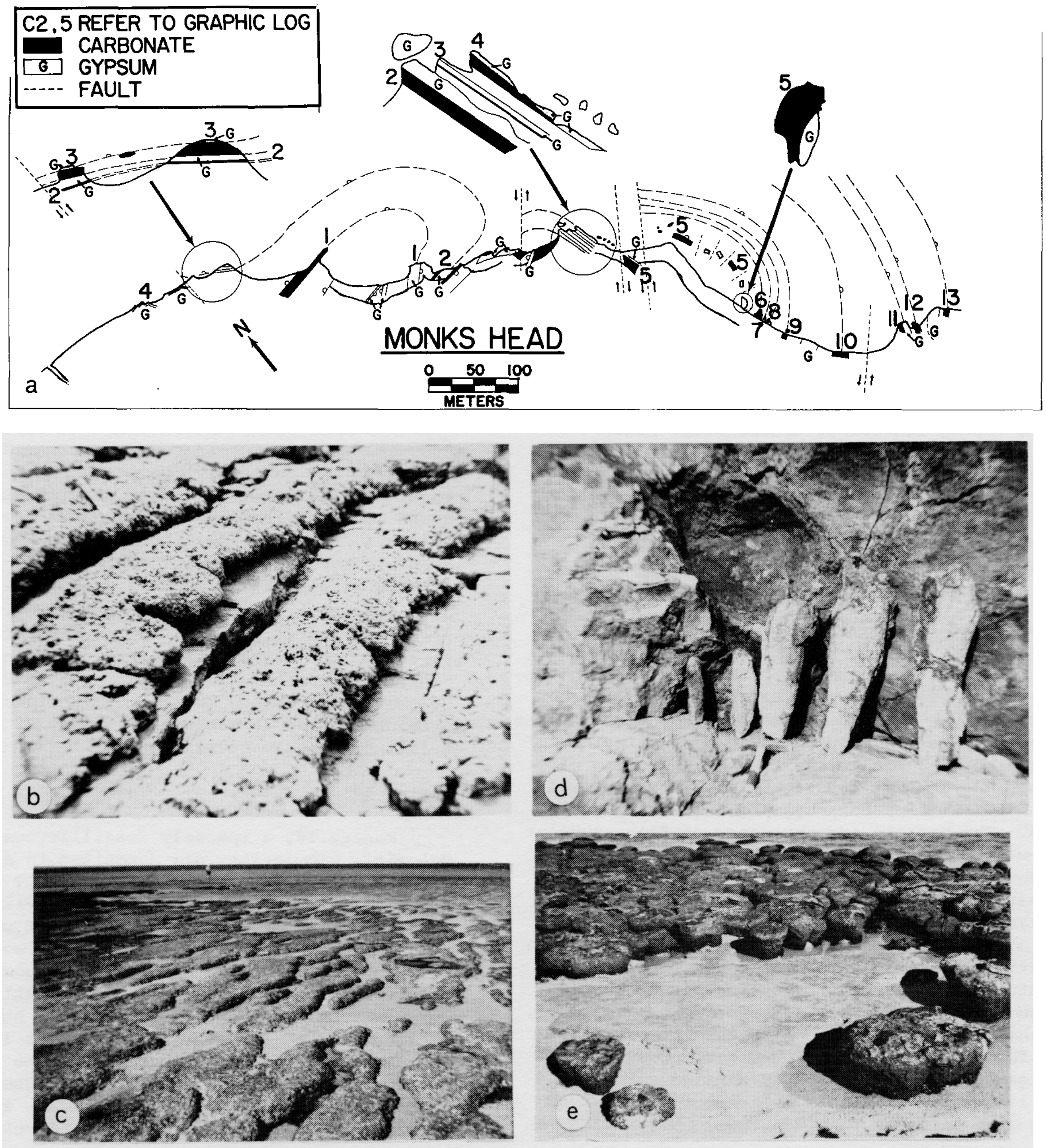
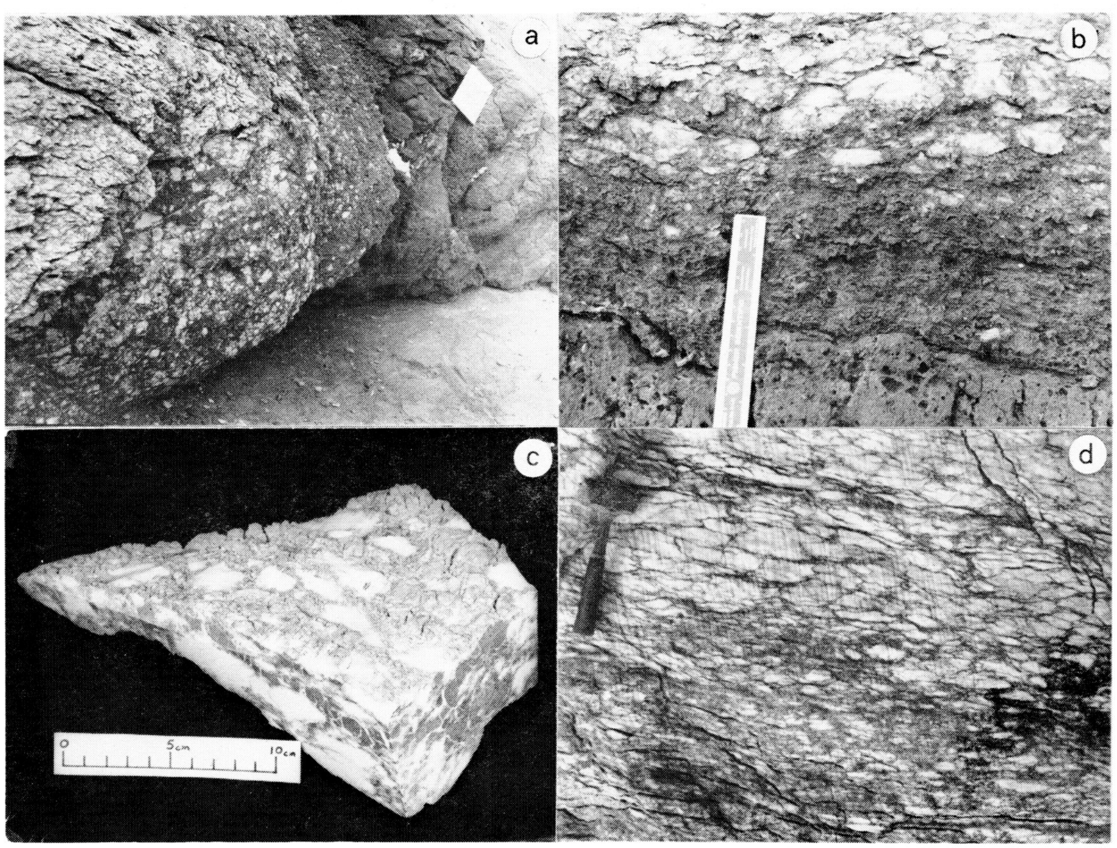


Fig. 6. Monk's Head Section (Stop 11). (b) Intertidal linear, ridge-rill algal stromatolites with flat (lower intertidal) to pustular (upper intertidal) texture resting on oolite (Monk's Head, Stop 11). (c) Similar stromatolites at Shark Bay. (d) Intertidal, discrete, columnar algal structures of a Windsorian headland (Port Hood). (e) Similar stromatolites to 6(c) at Shark Bay. Quiet areas between protecting clubs are capped by flat-lying, laminar algal mat of the low intertidal zone (similar to the Macumber-type lithology).

Fig. 7. (a) Linear stromatolites of Fig. 6(b) overlain with gradational contact by nodular gypsum. Note increasing sulfate content and also deformation of nodules upward toward camera and away from protecting carbonate (Monk's Head, Stop 11).
(b) Close-up of gradational contact between carbonnate and overlying gypsum. Lower third is oolite; middle third is gypsum - deeply weathered, and disrupting silty, laminated dolostone; upper third is well-exposed, pure gypsum nodules.
(c) Nodular gypsum block showing brecciation of laminated dolostone by nodules. Nodules are squeezed into prolate ellipsoids (Monk's Head, Stop 11).
(d) Nodular gypsum within modular, "chicken-wire" mosaic of silty, bituminous dolomite. Nodules have been squeezed to yield false stratification (Monk's Head, Stop 11).

Facies V

Facies V contains a profusion of algal stromatolites which accurately mark the intertidal zone. Because stromatolite form appears to be delicately controlled by environment, detailed reconstructions may be attempted. Flat-lying to spaced, laterally linked hemispheroids (Figs. 5 and 9) previously mentioned in the Windsor Group (Schenk 1967 a,b) apparently record the marine, intertidal, mud-flat environment mainly in protected locations of re-entrant bays and behind barrier islands and ridges where wave-action was slight (Logan *et al.* 1974). Discrete columnar structures mark headlands and other locations where sea waves are moderate (Fig. 6 d and e). Under regressive conditions, the height of the stack may be an index of tidal range. In the Windsor Group, the heights of these clubs are well sorted by stratum, and range from 10 to 100 cm. Sulfate strata often have a thin basal layer of such clubs, resembling packed cigars. Long, linear, ridge-rill stromatolites, aligned perpendicular to the strandline, occur mainly at seaward margins of prograding flat-lying (Macumber-type) sheets. In the Windsor strata, the linear stromatolites (Fig. 6 b, c) are aligned consistently parallel with the cross-stratification dip-direction of the immediately underlying biosparite.



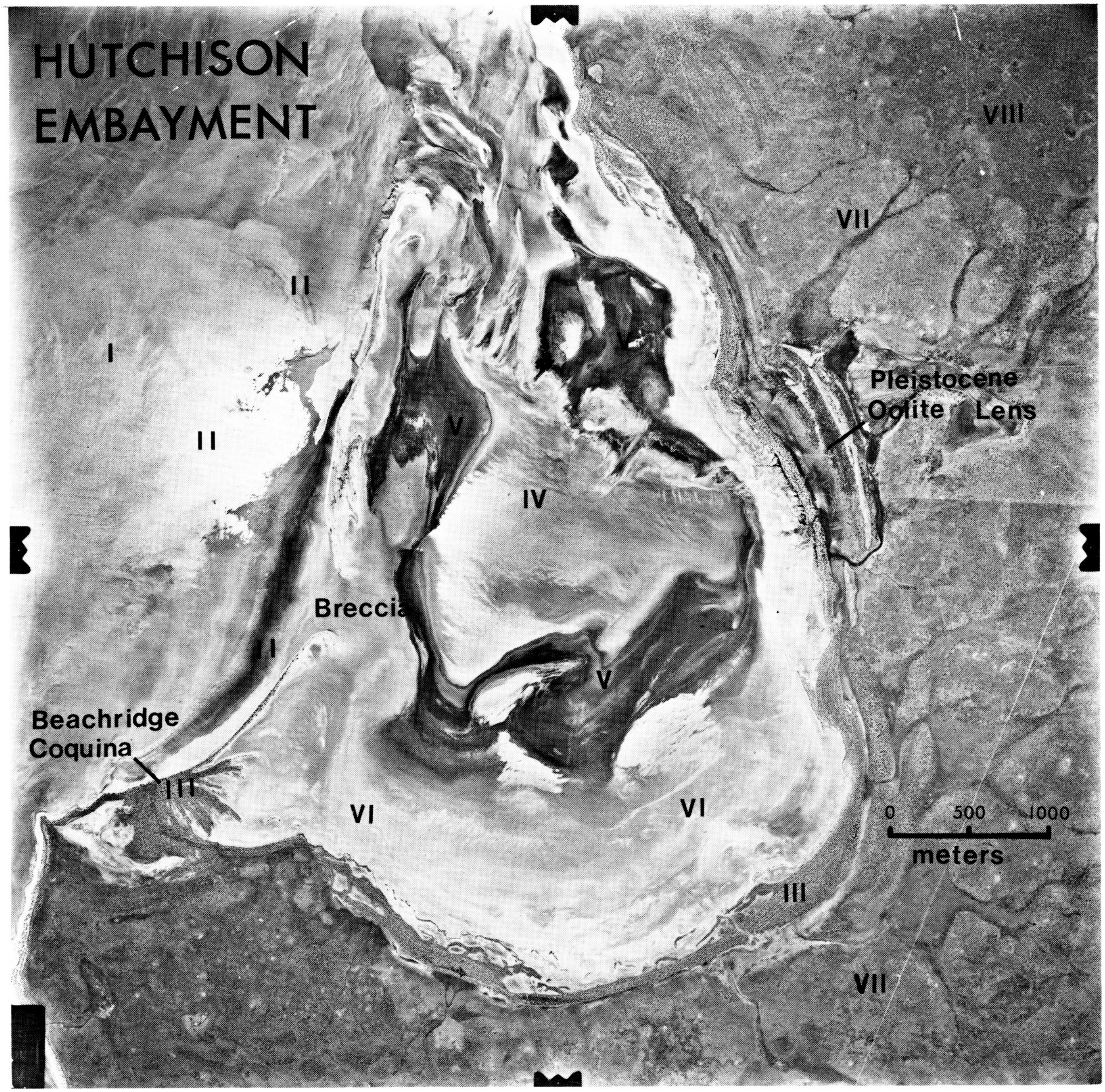


Fig. 8. Hutchinson Embayment, Shark Bay (see Fig. 4), showing specific lithotopes (numbered) whose comparable lithosomes are seen at Monk's Head. See Figs. 3 and 5 for identification of lithotopes.

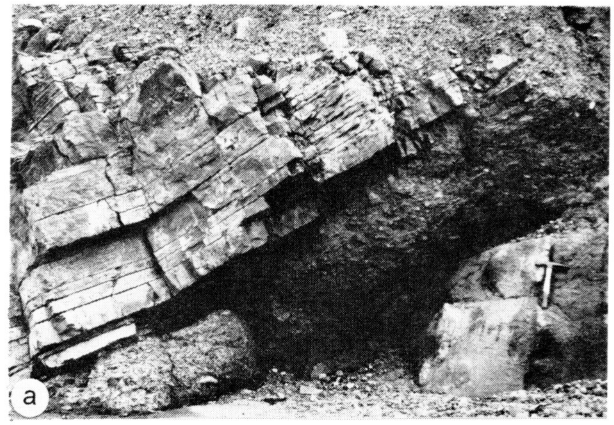


Fig. 9 (a) Angular unconformity between the Horton Group (hammer) and Windsor Group (basal fanglomerate) overlain by Macumber-type lithology (McIssac Point, Stop 9).

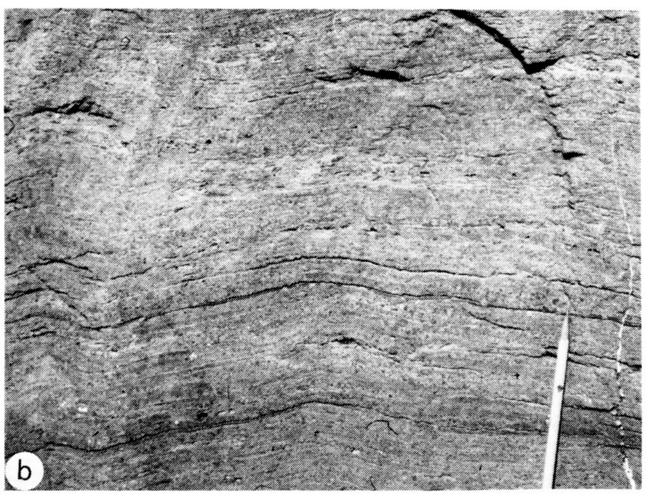


Fig. 9 (b) Lower lithosome of Macumber lithology showing thickly laminated wavy stratification (Stop 9).

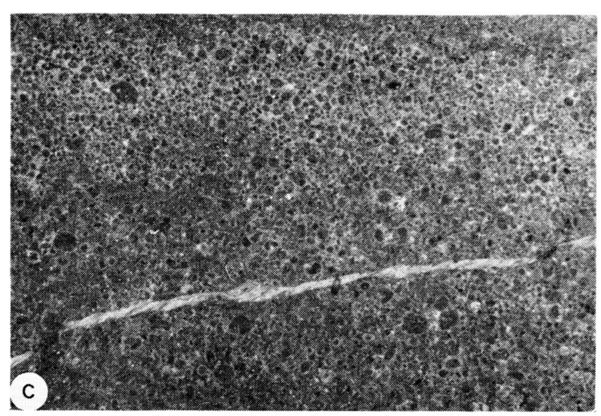


Fig. 9 (c) Microscopic view of a single laminae of Fig. 9b. Pellets are poorly sorted but groundmass changes upward through the laminae from micritic matrix to calcite spar.

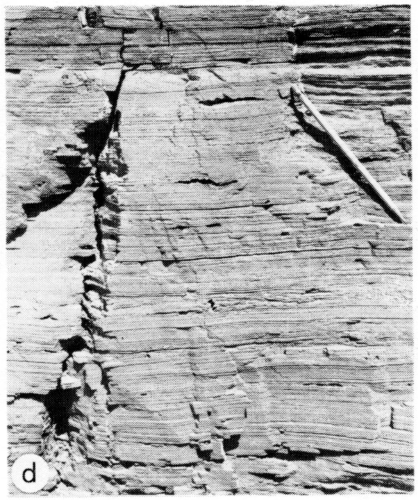


Fig. 9 (d) Upper lithosome of Macumber lithology showing thinly laminated, flat to crinkly stratification with brecciation, and deformed vugs (irregular fenestrae).

Fig. 9 (e) Microscopic view of Fig. 9d showing several laminae, each with clear calcite spar and silty, dolomite matrix. Note inverse grading in some calcite layers and their sharp lower contacts.

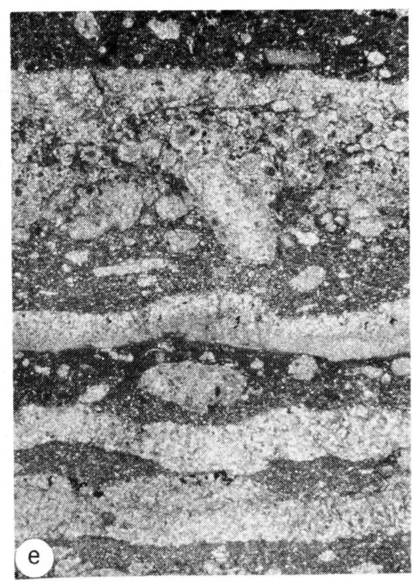


Fig. 9 (f) Limestone breccia associated with Macumber-type lithology. Note extreme angularity of clasts, and clast-composition restricted to upper lithosomes of Macumber-type. Interpreted here as jumbled prism-cracked polygons. See Figs. 5 and 8 for lithotopes (McIssac Point, Stop 9).

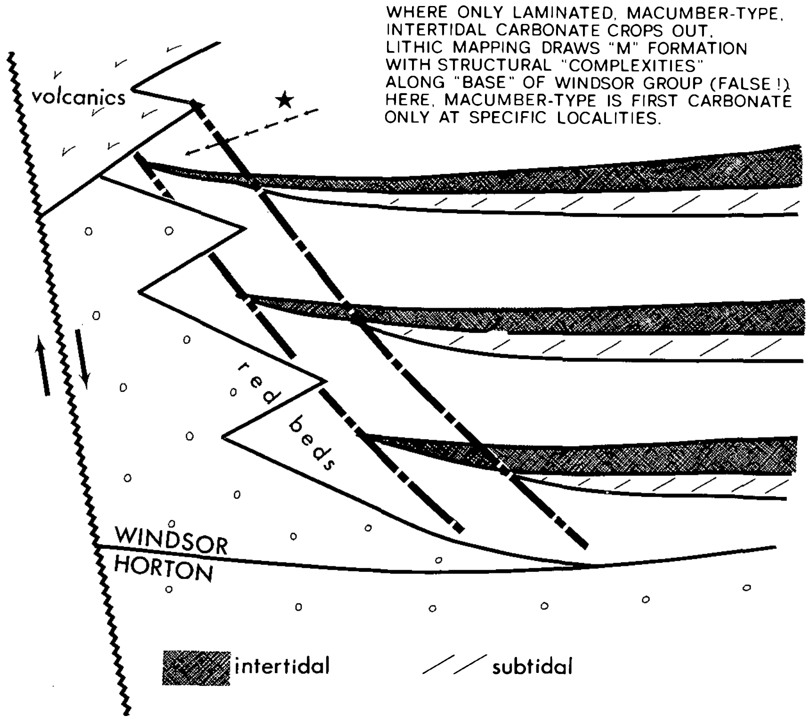


Fig. 10. Schematic cross-section across the Antigonish Basin to show confusion resulting from using lithostratigraphy as an immediate base for paleogeographic interpretations. At any single vertical section, intertidal Macumber-type lithic units will always be basal but all such units are not of the same age, only the same environment. Where only carbonates outcrop, and poorly at that, horrendous errors in structural and paleoenvironmental analyses lurk.

Facies VI

Facies VI, a complex lithosome of gypsiferous dolostone to dolomitic calcium sulfate, records the supratidal salt-flat environment with diagenetic, interstitial precipitation of both sulfate and microdolomite in unlithified carbonate sediment (Fig. 7). Most of the sulfate in the Windsor is in the form of massive, highly metamorphosed, porphyroblastic plutons, greatly deformed by late Paleozoic tectonics. Primary sedimentary structures have been obliterated wherever the sulfate has not been protected from such stress. In such refuges the primary structures are almost solely nodules.

Clearly, these nodules grew diagenetically from interstitial brine within a host of soft, quartz-rich carbonate (Fig. 7). The very sharp contact between sulfate and carbonate, the absence of impurities in the sulfate, the warped dolostone laminae (probably of surface, algal origin), the quartz silt (perhaps of surface aeolian origin), the warping of host dolostone, the absence of stratification in the sulfate, and in wide, transitional contact with carbonate, all argue against a replacement origin for the nodules. The continuous spectrum of fabrics ranging from obviously protected to badly stressed nodules argues against a simple boudin or ball-and-pillow origin. Rare, laminated sulfates of the Windsor Group could have been precipitated from standing water in supratidal salinas. Such marginal hypersaline lakes would fill topographic depressions which locally crossed the groundwater table. Perhaps considerable amounts of metamorphosed Windsor sulfate may have precipitated from such salinas or from severely restricted, lagoonal remnants.

Carbonate lithologies associated with the sulfate strengthens the hypothesis of a supratidal, algal stromatolite - nodular sulfate-refluxing secondary dolomitization mechanism. The supratidal carbonate is pelletted, brecciated, finely laminated, micro- to cryptocrystalline dolostone or calcitic dolostone with a very rare, abraded, and restricted fauna; it also contains intraclasts of algal stromatolites, abundant quartz silt, and remnants of blue-green algal mats. In general this lithology is very similar to that described by Shcenk (1967a, b) for upper lithosome B of the Macumber-like carbonate of the Windsor marginal facies. The upward Windsor succession of Facies IV, V and VI is mimicked in Shearman's (1966) "sabkhah cycle of sedimentation and early diagenesis" as seen today along the Trucial Coast of the Persian Gulf. As water is drawn from the lagoon by intense evaporation on the sabkhah surface, the brine becomes more concentrated while passing beneath and through the intertidal and low supratidal, hot, black algal mats. The intersitial precipitation of sulfate beneath the sabkhah surface produces a high-Mg dolomitizing brine, which diagenetically transforms aragonite mud into micro- to cryptocrystalline dolomite before continuing to depth and refluxing toward the sea. This refluxing brine secondarily dolomitizes and cements the more permeable seaward facies.

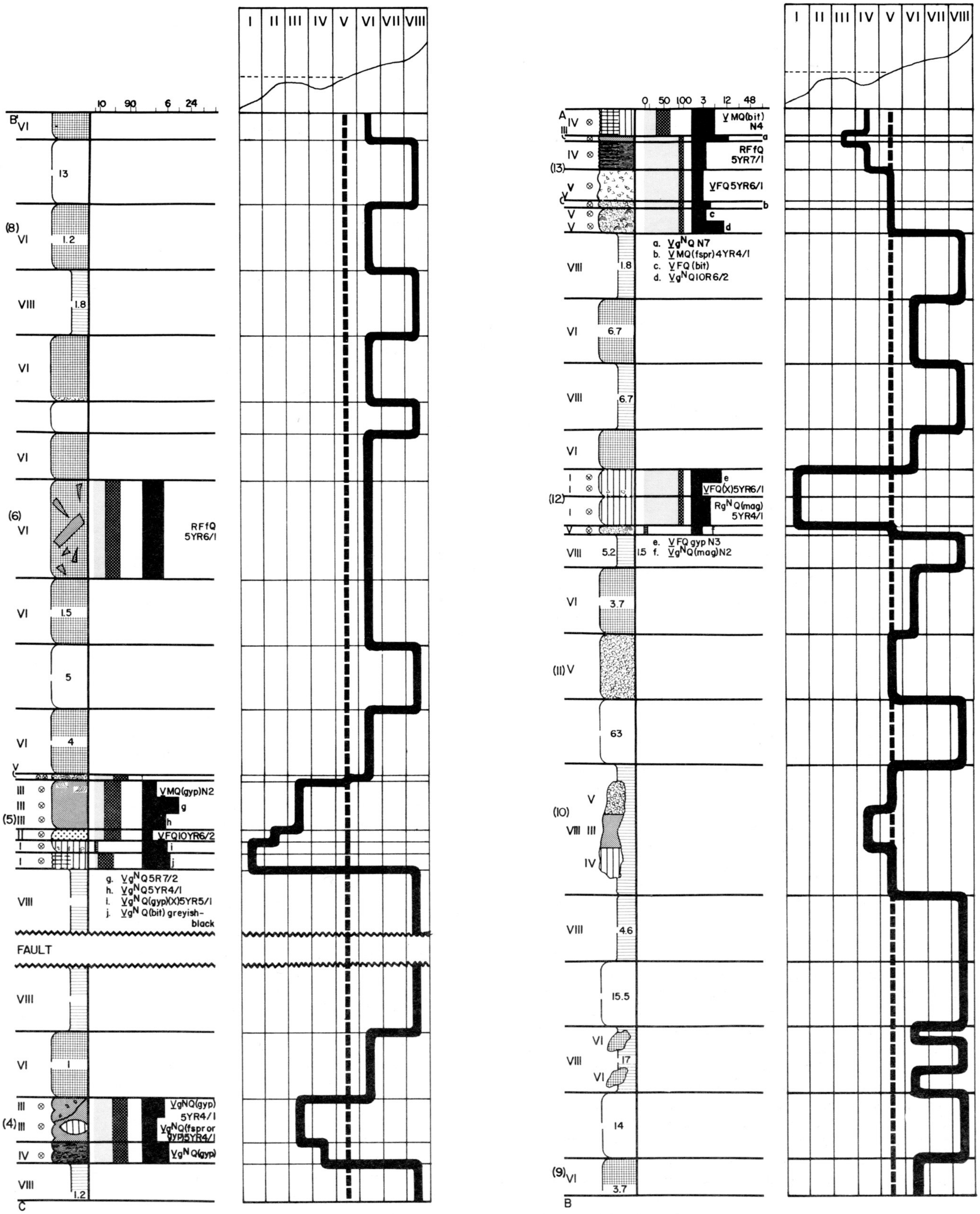
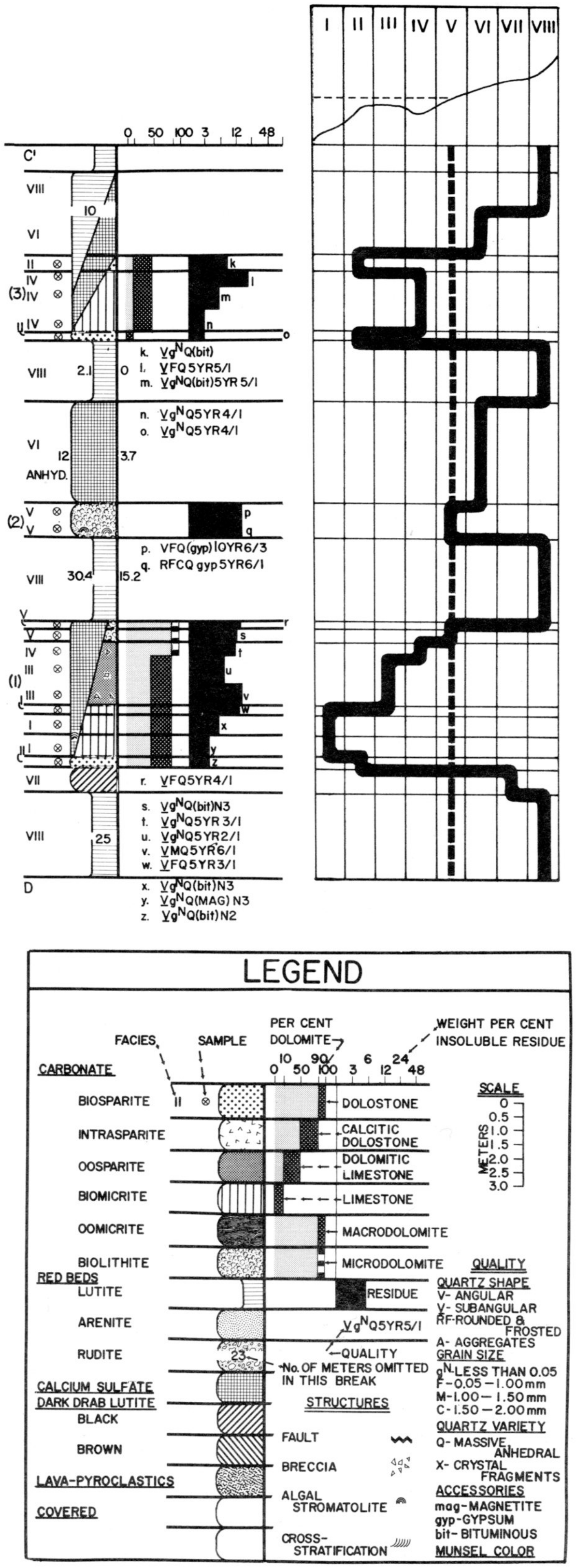


Fig. 11. Stratigraphic section at Monk's Head (Stop 11) showing data and environmental interpretation.



Facies VII and VIII

This complex of redbeds dramatically illustrates the segmented nature of the Fundy basin, the control of basin environments by intrabasinal uplifted blocks, and the marginward change of facies in both allogenic and authigenic sedimentary suites.

The coastal plain of northeastern Baja California, Mexico, is similar in climate and tectonic setting to the Carboniferous Antigonish-Mabou basin, except that in the former, carbonates constitute a very small part of the section. Alluvial fans derived from granitic highlands to the west coalesce to form an extensive plain at the foot of the highlands (Walker, 1967). A broad intertidal mud and salt flat up to 24 km wide and spotted with salt pans separates this plain from the open Gulf. The salt pans - the largest of which is nearly 8 km wide and more than 24 km long - are filled by sea water trapped and left behind after periods of high tides. Carbonate deposits are restricted to shell-rich beaches and oyster bioherms. The Pliocene-Pleistocene-Recent cross-section shows granitic rocks of the highland horst in sharp contact with a thick, red, fanglomeratic lithosome, which intertongues eastward with intertidal mud intercalated with lenses of dune sand, bedded gypsum, oyster bioherms, shelly beach-deposits, and finally marine, terrigenous sand. The Recent, Pleistocene, and Pliocene deposits record a hot, dry environment of relatively constant paleogeography and tectonic setting. The deposits show a progressive change from drab to red colour with increasing age. Walker (1967) illustrated how the red colour of arkosic fanglomerates on the flanks of highland source areas, and mud probably of intertidal and less likely shallow subtidal origin, formed *in situ* by intrastratal alteration if iron-bearing detrital grains, especially iron silicates such as hornblende and biotite.

In the Windsor Group, red mud, sand (with and without matrix), and boulder conglomerate are all stained; therefore rapidly alternating climate and soil profile of the source area are unwarranted (Van Houten 1968). Grain size increases steadily toward the Antigonish horst, which is composed of early Paleozoic acidic plutonic rocks, and both acidic and basic volcanics and metamorphic rocks. Adjacent to the highland scarp, the Rights River Formation (Murray 1960) of earliest Windsorian age is a coarse, poorly sorted, noncalcareous, pinkish red to green, prism-shaped, boulder to cobble fanglomerate up to 800 m thick, with angular to subangular clasts of pink granite, green quartzite, and rhyolite with shiny, red, iron-oxide coating. The formation rests with angular unconformity on earlier Horton redbeds (Stop 9). The matrix is of red sand and mud. The conglomerate thins rapidly in both directions along the basin margin and becomes finer-grained and structurally conformable with the Horton southeastward toward the basin center. Coarse, red, shoestring-shaped fanglomerates and sandstones of the early Windsorian 275-m thick Wilkie Brook Formation (Murray 1960) intertongue abruptly basinward with finer redbeds and strandline carbonates (Schenk 1967 a,b). The Wilkie Brook Formation (Stop 10) is succeeded vertically by several fault blocks in which at least 180 m of red, poorly sorted, coarse conglomerate is interstratified with red or green sandstones, gypsum, laminated carbonate, and at least five basaltic flows, each reaching up to 20 m in thickness. The association of coarse alluvial fans intertonguing with finer red sandstones and mudstones, the adjacent uplifted source, and the intercalatated thick sulfates and hypersaline carbonates, coupled with a similar tectonic setting, geographic location, and climate make analogy between the Windsorian basin and Baja California very tempting.

C. REGRESSION OF MODEL

Topographic irregularities would be controlled by relative rates of sedimentation and erosion. High rates of sedimentation would be in the high energy zone of the reefoid and oolitic shoal; however, high erosion rates would also characterize this belt because it was the source for most of the carbonate debris. Storms would transport debris seaward, but also landward to build beach-ridge coquinas behind the intertidal stromatolites, as well as storm-sheets and blow-outs in the salt flat. In these hollows, playa lakes and salinas would characterize the salt flat where standing watermasses occupied the topographic lows. As regression progressed, submarine topographic highs (e.g. the high energy zone, or grassmounds) would form islands and landward, large salinas (e.g. the old lagoon). As the salt pans were periodically replenished, halite, gypsum, anhydrite and potash could precipitate from standing water masses; however, much of the sulfate is nodular or deformed nodular. This sulfate is diagenetic, and grew within salt-flat sediments by evaporation of seawater drawn landward by "evaporite-pumping". An efficient engine for dolomitization is available either by this influxing brine, or by seaward seepage from beneath the playas/salinas.

Economics

Today, economic interest in the Windsor carbonates is intense. The Windsor holds the world's largest deposit of celestite. Halite, limestone and gypsum have been exploited for years, and gypsum is the largest mineral export of the province. Petroleum and potash exploration has continued for years, and today is concentrated on the Scotian Shelf. Discovery of rich deposits of lead and zinc in Windsor carbonates has promoted intense exploration activity. Both the celestite and the sphalerite are very early diagenetic, and are concentrated in and around algal stromatolites. The stromatolites are zones of high chemical activity because of fixing Mg in their sheaths, trapping and entangling unstable aragonite and high Mg calcite, and furnishing a reducing environment by incomplete combustion of algal tissue. The mats are highly permeable with both regular and irregular fenestrae, and can preserve this porosity-permeability feature after burial because of almost instant lithification at the sediment surface. The mat at the surface is dark in colour, usually black, which concentrates heat from the sun. Immense volumes of brine pass landward through this black, permeable-porous, chemically active filter, the buried stromatolite. Other low-supratidal deposits such as beach-ridge coquinas are also suitable host rock. Metallic trace elements have already been concentrated by evaporation in the lagoon. Perhaps metal content was higher than normal initially. The seawater represents the last presence of the Paleozoic Atlantic as the seaway closed to the south. This closure was due to subduction with attendant volcanism. I suggest a setting not unlike the present Red Sea (specifically the Afar triangle) with its metallic brines. Metallic concentration in strandline algal stromatolites and porous, beach-ridge coquinas should be the rule.

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