SHALLOW WATER REEFS OF THE MIDDLE DEVONIAN EDGECLIFF MEMBER OF THE ONONDAGA LIMESTONE, PORT COLBORNE, ONTARIO, CANADA

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INTRODUCTION

The reefs of the Edgecliff member of the Onondaga Formation are a well known part of the geology of New York State and the Niagara Peninsula in Ontario, Canada. Over the past thirty to forty years, the Onondaga and its reefs have been the subject of a number of Master's theses and Doctoral dissertations (see Wolosz, 1984, for references), and yet there are still a large number of unanswered questions regarding these reefs and the Onondaga in general.

The Edgecliff has generally been assumed to represent a warm, tropical, shallow water environment due to its abundant and diverse coral fauna. However, the lack of stromatoporoids and calcareous algae is a notably unusual feature for Devonian reefal limestones. The absence of these organisms lead Kissling and his students (Kissling, 1987; Kissling and Coughlin, 1979; Cassa and Kissling, 1982) to interpret these reefs as deep water structures. They have also pointed to the absence of peritidal facies in the Onondaga as added support for this interpretation, suggesting that the preserved Onondaga represents a deep water facies, the shallow water facies which rimmed the basin having been removed by erosion.

Studies of other Edgecliff reefs have yielded results which do not support this interpretation. The Thompson's Lake bioherm has been interpreted as having grown into the surf zone (Williams, 1980), while the LeRoy Bioherm has been interpreted as a shallow water deposit by Poore (1969), Lindemann (1988), and Wolosz (1988). Wolosz (1984, 1985) presented evidence of coral breakage and overturning to argue for shallow water conditions during reef growth at Roberts Hill and Albrights Reefs.

This field trip will examine the Ridgemount and Quarry Road bioherms, which are being interpreted by the author as the shallowest water reefs known from the Onondaga.

STRATIGRAPHY

Our current understanding of the Onondaga is due, in large part, to the work of Oliver (see Oliver, 1976, for extensive reference list), who used gross lithology and fauna to subdivide the Onondaga into the Edgecliff, Nedrow, Moorehouse and Seneca members. Lindholm (1967) later subdivided the Onondaga into four petrographic microfacies which in some areas deviate greatly from Oliver's stratigraphy (Figure 1), while Coughlin (1980) and

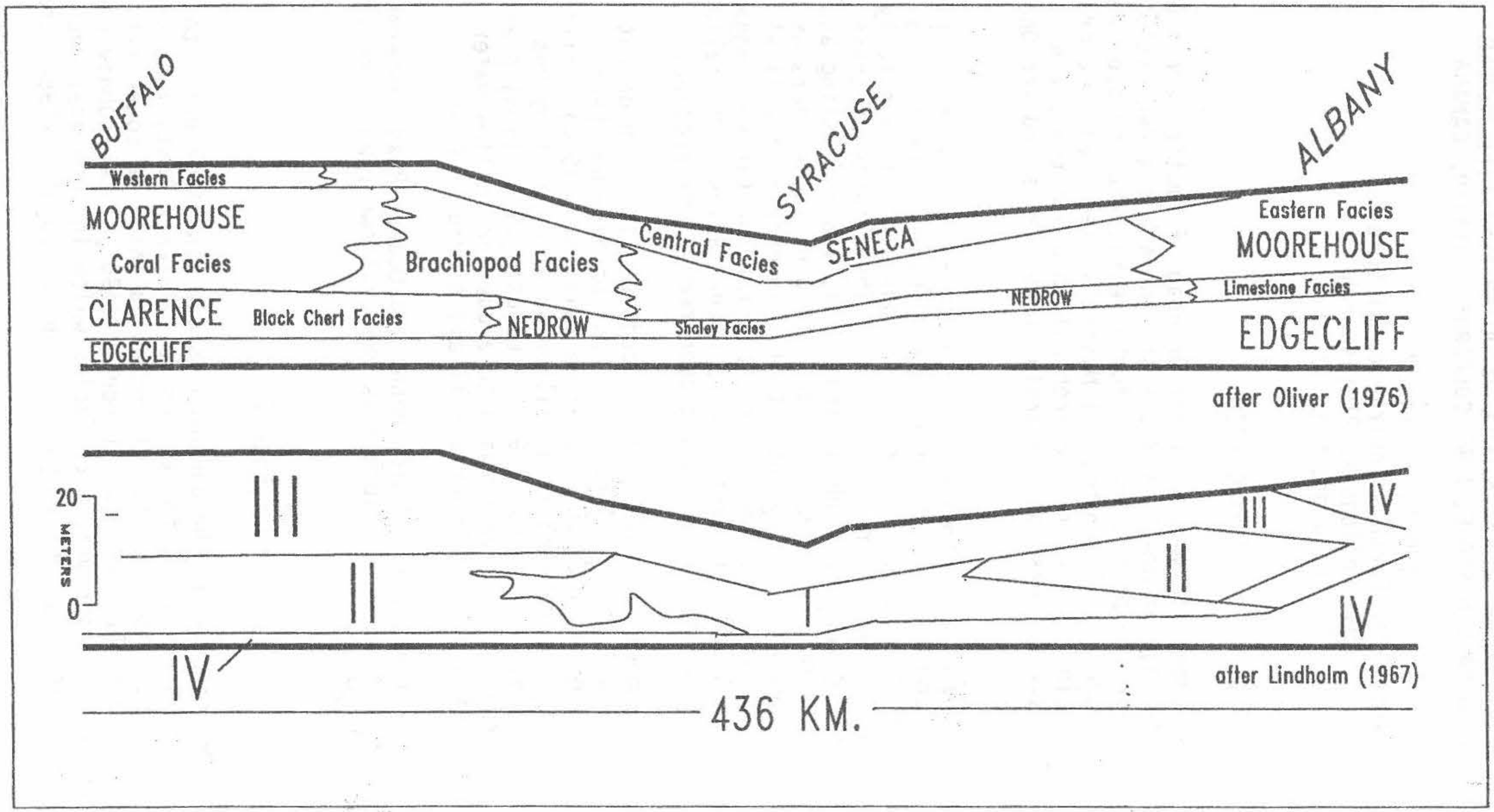

Figure 1. Onondaga stratigraphy and facies distribution. Upper cross-section illustrates Oliver's (1976) designation of members and facies based on biostratigraphy and megascopic rock characteristics. Thin Cl in east not shown. Lower cross-section illustrates Lindholm's (1967) microfacies distributions (I=fossiliferous calcisiltite with about 25% clay and less than 10% fossils; II=fossiliferous calcisiltite with about 5% clay and less than 10% fossils; III=bio-calcisiltite with 10-50% fossils; and IV=biosparite and bio-calcisiltite with greater than 50% fossils.)

Cassa (1980) presented interpretations of Onondaga subsurface stratigraphy across much of central and western New York State.

The Onondaga ranges up to approximately 34 meters in thickness in the eastern part of New York, but with the exception of the basal 2 meter "C1" micrite, it consists of crinoidal packstone/grainstone which is divisible into members only on the basis of biostratigraphy. In central New York, the formation thins to roughly 21 meters, but is easily divided on lithologic grounds into Oliver's four members, with the Edgecliff a massive, biostromal, very coarsely crystalline limestone from about 2.5 to 7.5 meters thick; the Nedrow a thin bedded, very fine grained shaley limestone; the Moorehouse a very fine grained limestone with chert and shaley partings; and the Seneca similar to the Moorehouse lithologically, but with a different fauna. Near Buffalo the formation reaches a thickness of 43 meters with only a very thin Edgecliff unit (about 1.5 meters). The Nedrow equivalent in this area is a sparsely fossiliferous, fine grained, chert-rich limestone which Ozol (1963) named the Clarence member. Both Lindholm (1967) and Messolella (1978) identified the central New York Onondaga as representing the most basinal facies exposed at the surface, and located the topographic axis of the basin through that area (Fig.2A).

The basal contact of the Onondaga is marked by a widespread unconformity (Rickard, 1975). In the east, the contact with the underlying Schoharie Formation has alternatively been interpreted as gradational (Goldring and Flower, 1942) or disconformable, with the presence of a glauconitic sand bed cited as evidence of a period of nondeposition (Chadwick, 1944). In the central part of the state, the base of the Onondaga is marked by the "Springvale Sand" which overlies either the patchily distributed Lower Devonian Oriskany Sandstone, or the older Helderberg limestones. The underlying units continue to be variable to the west, where the Onondaga rests upon either the Lower Middle Devonian Bois Blanc Formation or Silurian dolomites.

In the field trip area, the stratigraphy of the Onondaga is somewhat variable. In the Ridgemount Quarry the base of the Onondaga is marked by the presence of the green/gray fine "Springvale" sand which ranges from about 0.3 to 0.6 meter thick. The "Springvale" appears to be absent to the east of the coral mounds, where the contact is marked by a gray limestone with common solitary rugosans and intraclasts.

Above the basal unit, the northeast side of the quarry is characterized by coral beds, the north side by crinoidal grainstone/packstone interbedded with the "Springvale", and the west and south quarry walls by a roughly 0.3 to 0.6 meter clayey layer. The remainder of the exposed Onondaga along the south and west quarry walls, and the west portion of the north quarry wall consists of a gray-green biostromal limestone with abundant blue-black chert nodules. This unit is also present above the coral beds, where it is somewhat more shaley and roughly 2.7 to 3.6 meters thick; but here it is capped by a coarse bioclastic carbonate sand with abundant coral, which can be seen to pinch out along the north wall of the quarry.

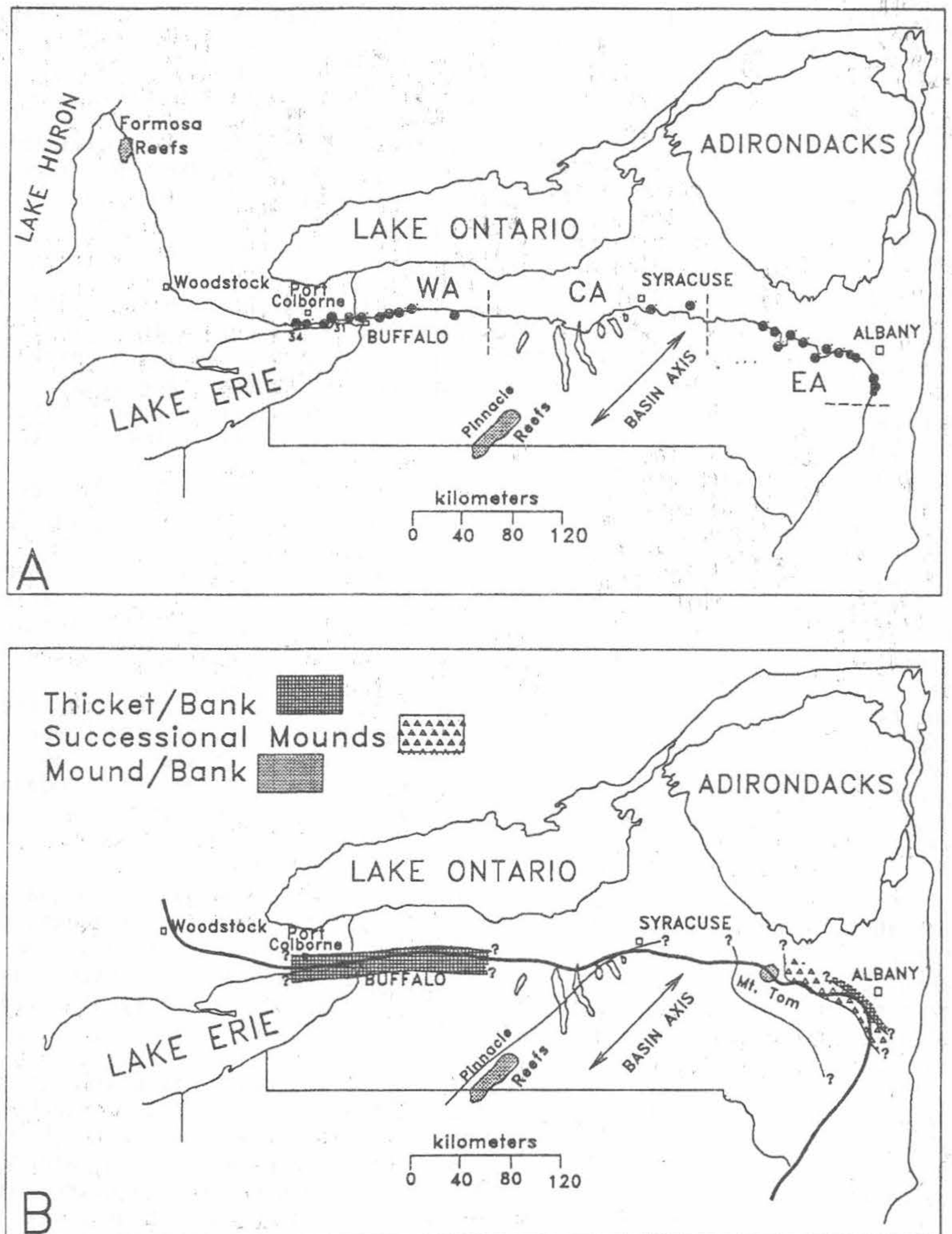

Figure 2A. Distribution of reefs along Onondaga strike belt (dots) in New York and Canada. Refer to Oliver (1976) for locality data. Bioherm #31 is Ridgemount Bioherm, #34 is Quarry Road Bioherm. Pinnacle reefs are subsurface. Formosa reefs are Edgecliff equivalents. Note position of basin axis. 2B. Distribution of Edgecliff reefs by type.

To the southwest, at the Quarry Road exposure and the active quarry on the north side of Route 3 (former Law Quarry), the basal Onondaga is marked by roughly 1.8 to 2.1 meters of greenish, shaley limestone with clay seams and sparse to common coral, followed by from 1.0 to 2.4 meters of limestone which varies from dark gray to light gray to buff with varying densities of clay seams, but characterized by abundant *Cystiphylloides*, a solitary rugose coral. At the former Law Quarry, and along the west wall of the West Quarry at Quarry Road, the remaining Onondaga is a chert rich, biostromal, micritic limestone with colonial coral. Along the east wall of the West Quarry, the *Cystiphylloides* biostrome is capped by a grainstone bed with abundant coral and stromatoporoids. At the south end of the quarry a number of small coral mounds are exposed which are stratigraphically above this grainstone bed and grade laterally into the chert rich, micritic Onondaga facies.

REEF COMMUNITIES

Most Edgecliff reefs include two distinct communities - the Phaceloid Colonial Rugosan Community and the Favositid/Crinoidal Sand Community.

The phaceloid colonial rugosan community is made up almost exclusively of colonial rugosans. Common genera include *Acinophyllum*, *Cylindrophyllum*, and *Cyathocylindrium*; with *Eridophyllum*, *Synaptophyllum*, and possibly phaceloid colonies of *Heliophyllum* as accessories. The dense growth of these rugosan colonies appears to have restricted most other organisms to only minor roles, with favositids (both domal and branching) being small and rare, brachiopods uncommon, and bryozoans mainly fragmentary encrusters.

The favositid/crinoidal sand community displays a much higher diversity than the rugosan community. This community is more biostromal than biohermal. Large sheet-like to domal favositids are abundant, but never form a constructional mass. Solitary rugose corals are also extremely abundant as are fenestrate bryozoan colonies. Single colonies of the mound building phaceloid rugosans are occasionally found. Brachiopods and other reef dwellers are also common although never extremely abundant. Stromatoporoids and massive colonial rugosans, while extremely rare in the Edgecliff reefs, when found are part of this community. The crinoids were the greatest contributor to this community - ossicles making up the bulk of the rock and indicating abundant growth of these organisms - but complete calyces are never found.

REEF CLASSIFICATION

The Edgecliff reefs represent a continuum of growth pattern in which the two communities described above (Phaceloid Colonial Rugosan and Favositid/Crinoidal Sand) are the pure end members. Hence, a simple classification of these reefs is as follows:

Mounds - distinct high relief mounds of the Phaceloid Colonial Rugosan Community. Subdivided into:

1) Successional Mounds - rugosan mounds up to roughly 15 meters thick which display an internal succession of mound building colonial rugosan genera.

2) Small Mounds - small monogeneric to mixed fauna buildups. Generally not more than 1 - 3 meters thick. Commonly found in protected back-reef areas. At least five such structures are known from the field trip area.

Composite Structures - structures formed through interbedding or intergrowth of the two communities. The term "bank" follows the definition of Nelson, et al. (1962): "a skeletal limestone deposit formed by organisms which do not have the ecologic potential to erect a rigid, wave resistant structure." Subdivided into:

1) Mound/Bank - large structures resulting from the repetitive intergrowth of rugosan mounds and the favositid/crinoidal sand facies. Subsurface pinnacle reefs reaching up to 60 meters in thickness represent this type of structure.

2) Ridge/Bank - Colonial rugosans and occasional large favositids form a series of small mounds which coalesce laterally to form an elongate, ridge-like structure. The Ridgemount Bioherm is the only known example of this reef type.

3) Thicket/Bank - The favositid/crinoidal sand facies makes up the main mass of these buildups in the form of gently dipping (5 to 12 degrees), bedded packstone and grainstone with abundant large sheet to domal favositids. The colonial rugosans occur as thickets roughly 0.3 meters thick, which cover the entire bank, and are now interbedded with the biostromal deposits. The resultant structure is a low relief, shield shaped mound up to approximately 300 meters in diameter and 15 meters thick.

Biostrome - bedded Favositid/Crinoidal Biostrome, typical bedded Edgecliff, with no evidence of relief above sea-floor. Banks of pure Favositid/Crinoidal Community have not been recognized, although some Thicket/Bank structures are, volumetrically, very close to this state.

PATTERNS OF EDGECLIFF REEF GROWTH AND THEIR GEOGRAPHIC DISTRIBUTION

Oliver (1976) has presented location data for both the known Edgecliff reef exposures and subsurface reefs (Figure 2A). When the reefs are described using the classification outlined above, and this data added to the reef distribution map, the following patterns emerge (Figure 2B).

The large mound/bank structures rim the axis of major basinal subsidence. Wolosz (1984, 1985, 1989a, 1989b) has argued that the dominant reef community in Edgecliff Reefs was controlled by the level of water turbulence at the crest of the reef. Following this model, Wolosz and Paquette (1988) suggested that the shifts between the Favositid-Crinoidal Sand Community and the Colonial Rugosan Community mark "catch up/fall back" growth cycles as the reef community attempted to maintain itself at a constant water depth during basinal subsidence. The balance of growth versus subsidence resulted in the great thickness of these reefs.

In the east, an off-shore to on-shore trend from mound/bank through successional mounds to thicket/banks is notable (Figure 2B). This is interpreted as a shift from deeper to shallower waters, based upon both geographic considerations - the Adirondack Mountains having been a low land mass to the north, while deeper water lay to the south - and by basinal facies patterns - the mound/bank and successional mound reefs are rooted in the micritic, deeper water Cl Edgecliff facies, while the thicket/bank structures are rooted in the typical grainstone/packstone of the Edgecliff. Further, the thicket/bank structures are characteristic of the assumedly shallow water, western transgressive facies of the Edgecliff from the vicinity of Rochester, westwards into Ontario, Canada (Figure 2B).

The Ridgemount Quarry is the only known example of a ridge/bank reef. Its location roughly 3 kilometers to the north (up dip and shoreward) of the main trend of thicket/bank reefs from Fort Erie to west of Port Colborne suggests a shallower water environment than that in which the thicket/bank reefs formed.

Figure 3 illustrates the water depth relationship among the various reef types.

THE EDGECLIFF REEFS - COOL WATER STRUCTURES?

As mentioned in the introduction, Kissling and his students have pointed to the lack of stromatoporoids and calcareous algae, in conjunction with the absence of clear peritidal deposits to suggest that the Edgecliff reefs may have been deposited in deep water. An alternative hypothesis to the deep water model is for the Edgecliff reefs to have been deposited under cool water conditions. Wolosz and Paquette (1988) suggested a cool water environment for the Edgecliff, as have Koch and Boucot (1982), based on the Edgecliff brachiopod fauna, and Blodgett, et al. (1988), based on gastropod faunas.

The model presented by Wolosz and Paquette (1988) suggests a westward current flow across New York and on into Canada, with water temperatures gradually increasing due to solar warming. Evidence of this trend may be found in the increase in stromatoporoid abundance across New York State and into Canada. In eastern New York stromatoporoids are extremely rare and generally small. Near Rochester (LeRoy Bioherm) they are larger (up to about 0.3 meter in diameter, but only a few centimeters thick), but still uncommon. In the Quarry Road exposures, stromatoporoids are quite common in the carbonate sand facies, still thin, but up to 0.9 to 1.5 meters in diameter.

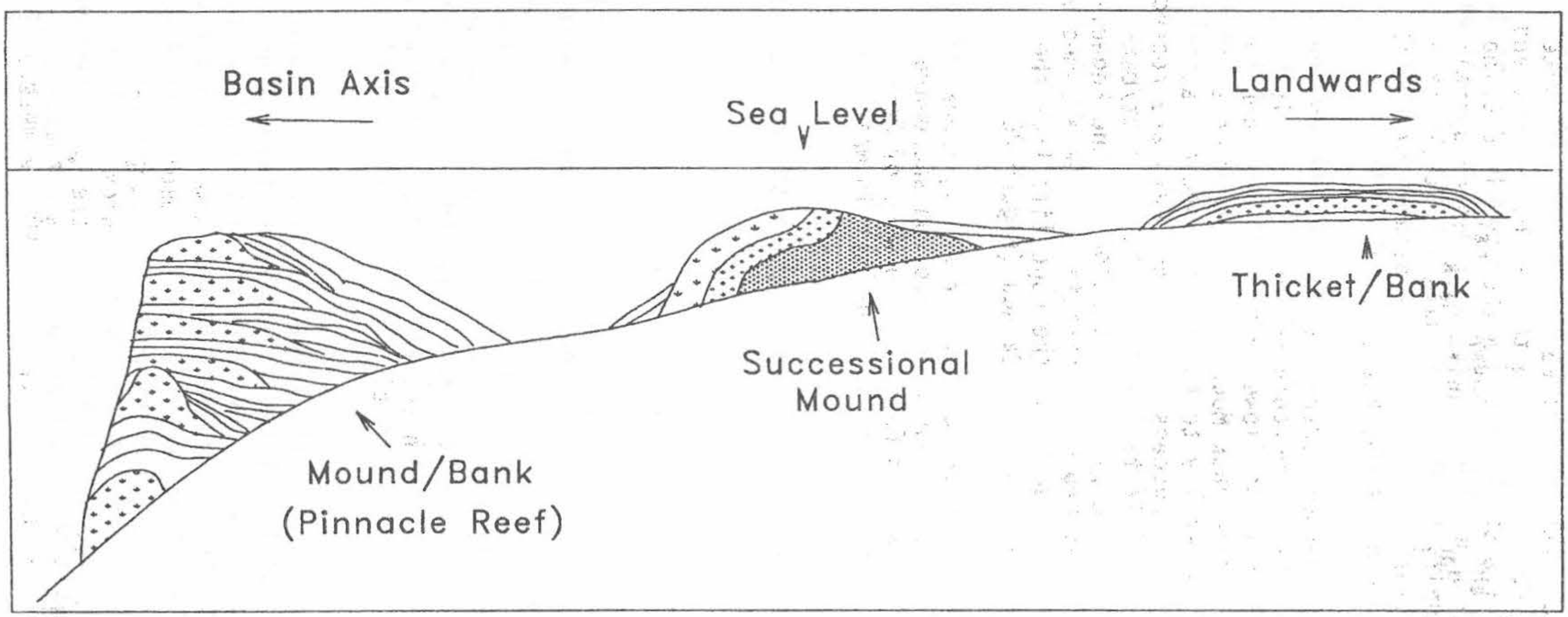

Figure 3. Water depth relationship of reef types. Mound/bank structures indicate areas of subsidence, with active mound growth only at top of structure. Final reef structure is made up of stacked mounds interbedded with favositid dominated, crinoidal grainstone/packstone flank beds. Successional mounds are characteristic of areas of minimal subsidence, although sea-level fluctuation would control coral succession. Flank beds surround the mound. Thicket/bank structure represents shallowest water conditions of three reef types. Colonial rugosan occur only as thickets interbedded with favositid dominated crinoidal sand flanks. Reefs are not drawn to scale.

Finally, the lack of peritidal facies may simply reflect our over-reliance on the tropical Bahamian model for limestone deposition. Lees (1975) illustrated world trends in carbonate deposition, illustrating the fact that temperate water limestones (Foramol Association) do not occur with algal mats, ooids or any of the other tropical carbonate facies.

FIELD TRIP STOPS

Ridgemount Bioherm (STOP 1).

Figure 4A is a map of the Ridgemount Quarry. Note that reef facies are restricted to the northeastern quarter of the quarry. The north wall of the quarry exposes a number of bioherms (Satellite bioherms), while a single bioherm can be examined in the east wall, just north of the water filled section of the quarry (Bioherm A). The northeast wall of the quarry displays abundant coral in a bed which pinches and swells from about 0.7 to roughly 2 meters thick (Coral Beds).

Cassa and Kissling (1982) interpreted the Edgecliff in this quarry as consisting of numerous small bioherms, which is, to a large degree, correct. However, it is important to note the dip of the beds which overlie this coral bed (in particular the quarry walls surrounding tank cars on Upper Level). These exposures are above and to the east of the Coral bed exposure, but they are already dipping westwards, indicating that these small mounds existed behind a larger structure to the east. While the dip has to some degree been enhanced by compaction (especially around Bioherm A), a pinch out of these beds can be observed along the north wall of the quarry, indicating a primary depositional dip. Further, examination of the beds behind the tank cars reveals numerous thickets of *Acinophyllum* and small branching tabulate corals. These thickets have not been observed elsewhere in this quarry, suggesting colonization of a topographic high on the sea-floor. Finally, note the top of the quarry wall (good exposures may be found along the quarry rim above the tank cars, also above Bioherm A) which consists of a clean biostromal sand containing large phaceloid rugosan colonies (*Cyathocylindrium*?) and abundant solitary rugosans and favositids. This facies appears to be restricted to the general vicinity of the stratigraphically lower coral buildups, also supporting the presence of a topographic high on the sea-floor.

Examination of the coral buildups (Bioherm A, Satellite bioherms, coral beds) reveals little internal structure. Unlike the well developed rugosan thickets commonly found in thicket/bank structures or the dense growth of colonial corals within mound structures (as will be seen at the Quarry Road bioherms), these buildups are most commonly characterized by debris and overturned and broken coral colonies (large overturned favositids are especially notable). Bioherm A (Figure 5) is easily accessible for examination. Note the absence of a well developed core facies in this structure. This unusual lack of internal structure is interpreted as indicative of very shallow water conditions during mound development. Intermittent high energy periods (storms) prevented the continuous coral

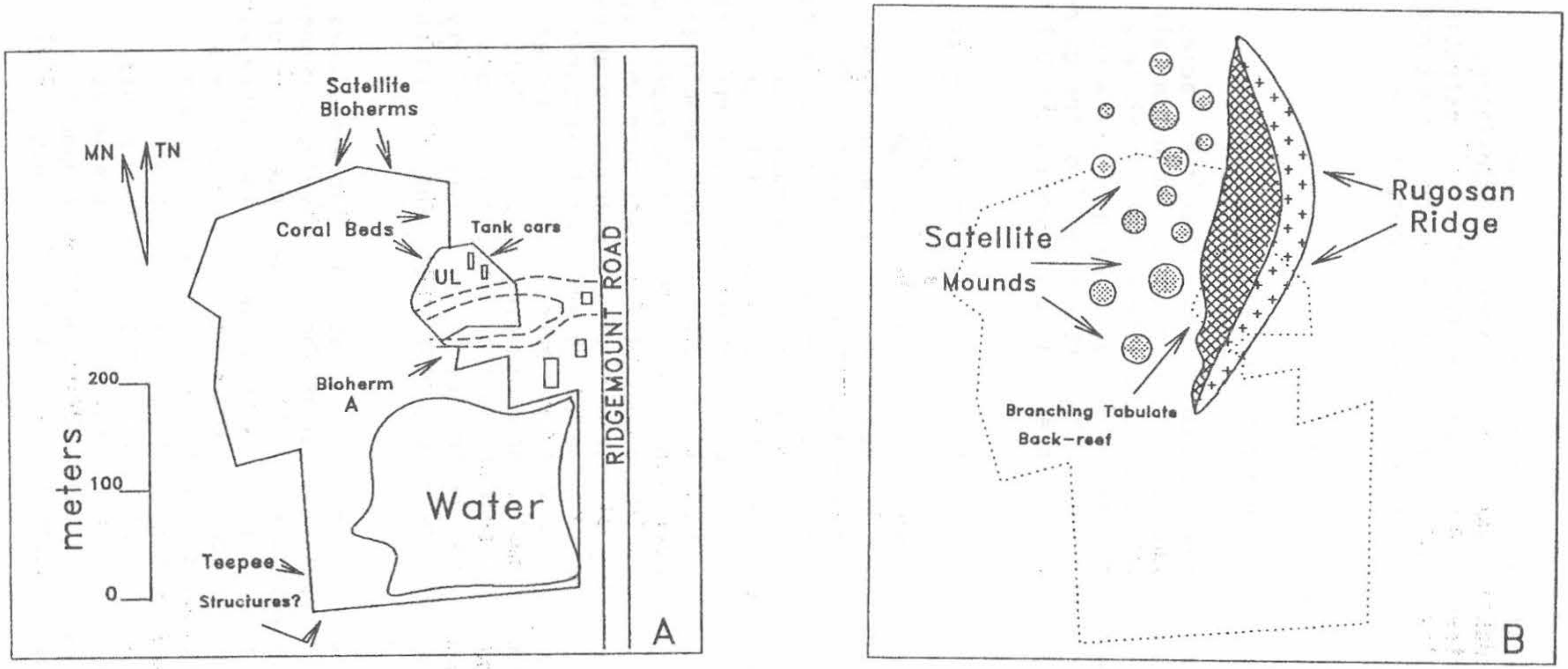

Figure 4A. Ridgemount Quarry. Coral Horizons restricted to the northeast quarter of the quarry. UL = Upper Level. Upper carbonate sand horizon is well exposed at top of quarry wall above Coral Beds and Bioherm A. Siluro-Devonain contact well exposed in western quarry wall and in floor of quarry near possible Teepee Structures. 4B. Interpretation of Ridgemount Coral buildup. Note outline of present quarry (dots). Rugosan Ridge is mainly debris pile formed through coalescence of small mounds. Branching tabulate back-reef presently exposed in quarry walls (Coral Beds, Fig. 4A). Presence of satellite mounds extrapolated from location of Satellite Bioherms in north quarry wall.

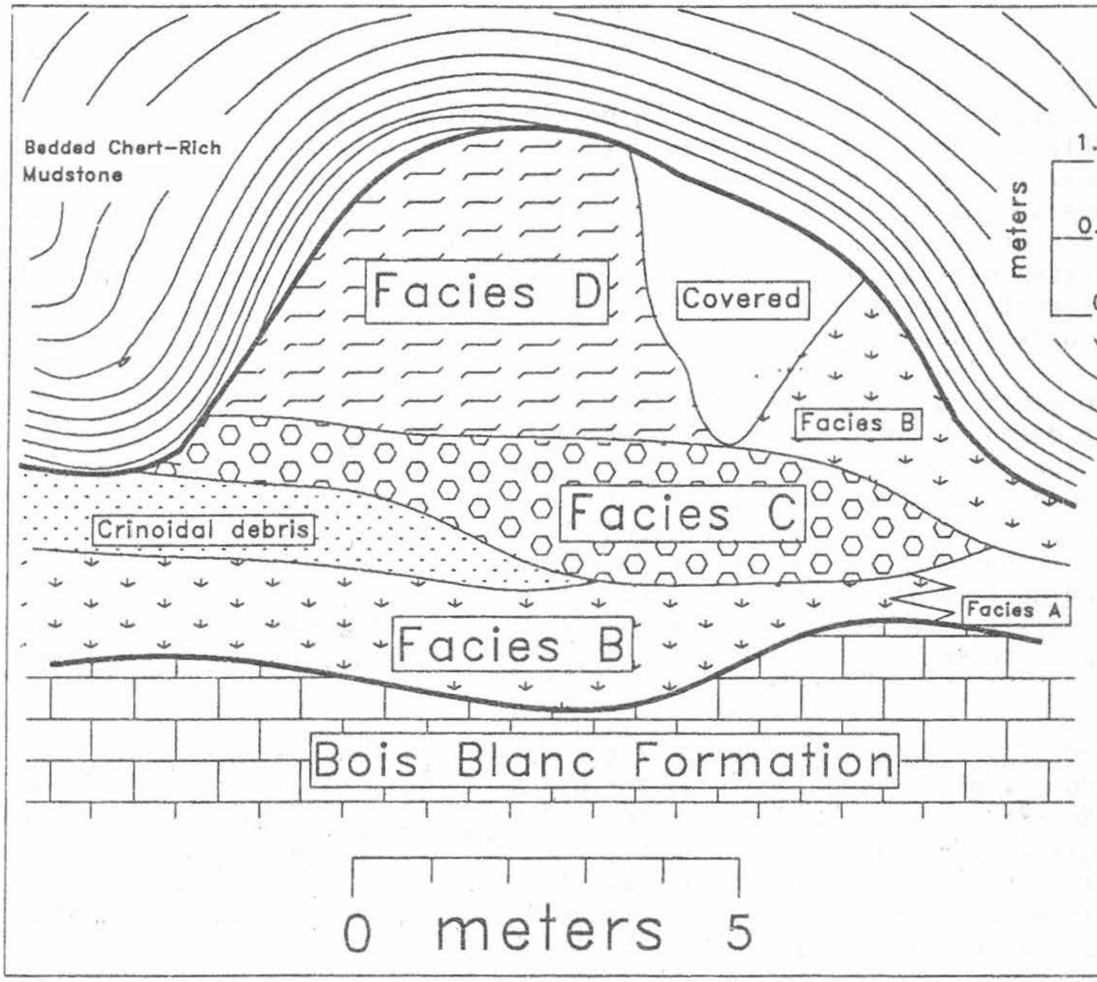

Figure 5. Bioherm A. Facies A - biostromal packstone with clasts of shale and underlying Bois Blanc Formation. Facies B - Acinophyllum rich biostrome with abundant small favositids and solitary rugose corals. Facies C - Acinophyllum, large phaceloid colonial rugosans and large solitary rugosans. Some possibly in-place. Facies D - Mainly coral debris, including Acinophyllum colonies, large branching tabulate corals and solitary rugosans. Most are overturned and fragmental. Overlying bedded chert-rich mudstone contains abundant large crinoid columnals characteristic of theEdgecliff. Dip of these beds has been exaggerated by compaction.

development seen elsewhere in the Edgecliff, and resulted in the debris-mound facies seen in this quarry.

A proposed model of the coral mounds and beds present in the Ridgemount Quarry is presented in Figure 4B. In this model, initial colonization of the shallow sea-floor lead to the development of small debris mounds (little in-place growth is preserved due to the battering of these mounds by waves). These debris mounds acted as sites for further colonization by rugosans, and as protection for tabulate corals colonizing the sea-floor to the lee of these mounds. Gaps between mounds would fill with storm generated debris, and then be recolonized by coral, eventually leading to the formation of an elongate "Coral Ridge", with small satellite bioherms in a back-ridge biostrome.

No other Edgecliff reef exposure exhibits such extensive evidence of storm damage, suggesting a shallower water depth than any other known structure. Further, evidence of the early growth of this structure following transgression over the exposed Bois Blanc (and therefore shallow water conditions) can be seen along the north wall of the quarry, to the west of the last satellite bioherm. There, the carbonate sand facies extending from the satellite bioherm interfingers with the basal "Springvale Sand", indicating that the growth of the satellite mound was coeval with the deposition of the "Springvale" only a few meters to the west.

Ancillary Topics at Stop 1. The west wall of the quarry exposes the Siluro-Devonian disconformity described by Kobluk, et al. (1977). This contact is characterized by borings which have been filled by quartz sand and glauconite. The underlying Silurian dolomite contains brecciated horizons. Excellent samples are available for class use. Finally, possible teepee structures are present in the Bois Blanc just below the contact with the Onondaga (see map Figure 4A).

Quarry Road Bioherm (Stop 2).

The West Quarry (Figure 6A) offers examples of two types of Edgecliff Reefs. Along the north wall two small, mono-generic mounds and some quarried blocks of mound facies are available for examination. The easternmost mound (and the bioherm blocks) consist of *Acinophyllum* colonies, while the western mound is predominantly *Syringopora*. Unlike the bioherms at Ridgemount these small structures exhibit dense, in-place growth of colonial coral.

At the south end of the quarry, exposed on a glaciated surface, are three small thicket/bank structures (Figure 6B) the largest of which is approximately 26 meters in diameter. These small mounds are made up of thickets of phaceloid colonial rugosans interbedded with biostromal beds of small branching tabulate corals. Again, compare the in-place preservation of coral in these small structures to the debris mounds at the Ridgemount Quarry, keeping in mind that we are now roughly 3 kilometers down depositional dip from the Ridgemount structures. Also note that these structures are quite small when compared to other thicket/bank reefs such as the roughly 245 meters diameter North Coxsackie Reef south of Albany and

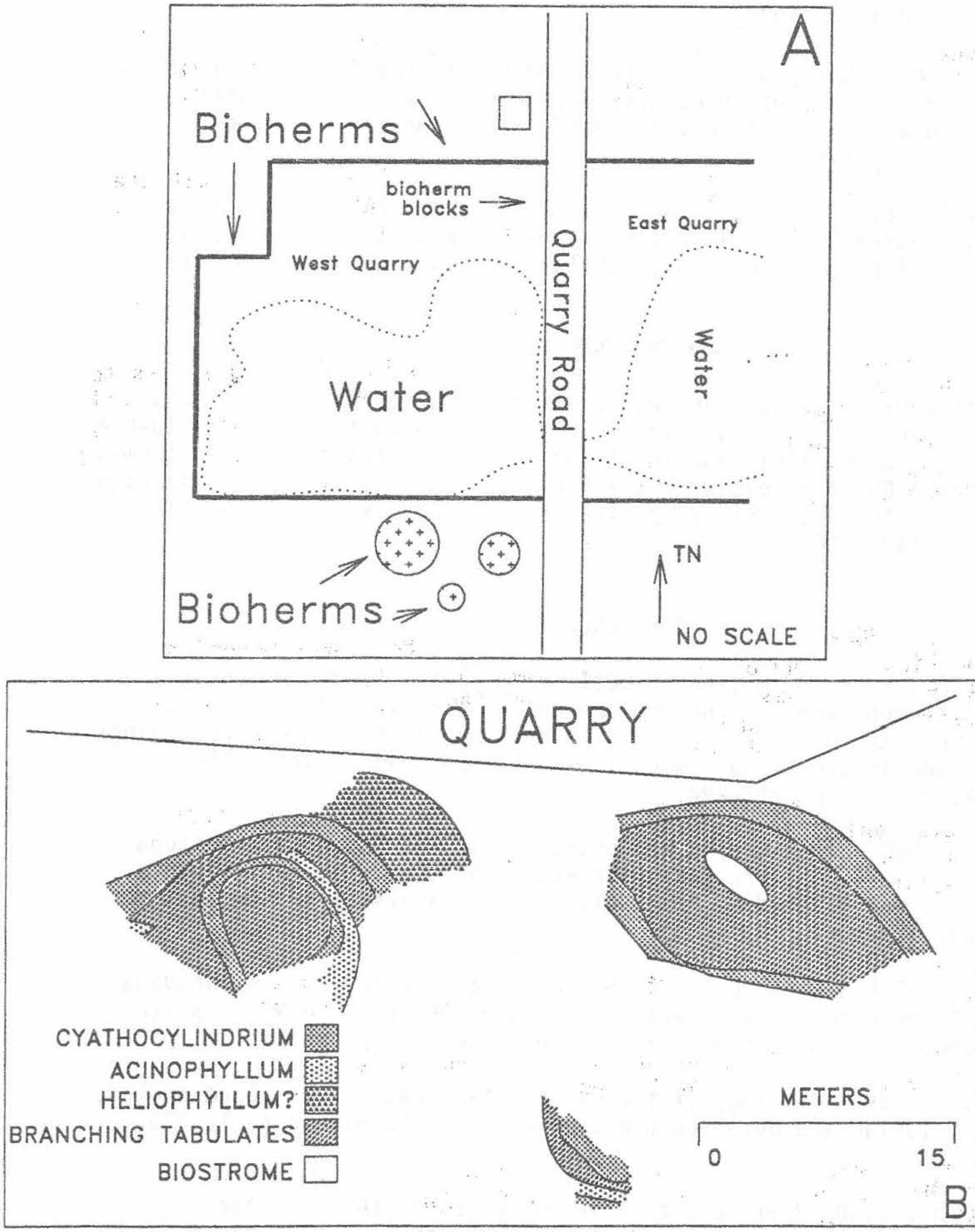

Figure 6A. Quarry Road Quarries.
6B. Detail of three small thicket/bank structures exposed at the southern end of the West Quarry.

the approximately 300 meters diameter Buffalo Country Club Reef (bioherm #'s 3 and 28 of Oliver, 1976).

Finally, examine the grainstone bed along the northeast and east wall of the West Quarry. Stromatoporoids have become quite abundant in this facies, and can also be occasionally found in the underlying, muddy *Cystiphylloides* biostrome.

Ancillary Topics at Stop 2. The Bois Blanc Formation floors both the East and West Quarries. Fossil collecting is excellent, with the quarry floor littered with loose rugosans, tabulate corals, and other fossils.

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ROAD LOG FOR SHALLOW WATER REEFS OF THE MIDDLE DEVONIAN
EDGECLIFF MEMBER OF THE ONONDAGA LIMESTONE,
PORT COLBORNE, ONTARIO, CANADA

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Toll both at Peace Bridge.
0.75	0.75	Canadian Customs Booths. Bare to right leaving customs booths.
0.95	0.2	Fort Erie Exit. Turn right at end of exit ramp.
1.35	0.4	Right turn at light onto Route 3.
5.65	4.3	Right turn onto Ridgemount Road.
6.45	0.8	STOP 1. Entrance to Ridgemount Quarry on left side of road. Park at quarry entrance. HARDHATS REQUIRED. Please beware of overhangs and loose rock. NOTE: Visitors should sign in at the quarry office 0.8 miles to the north.
7.25	0.8	Return to Route 3. Turn right.
22.95	15.7	Pass through town of Port Colborne. Turn right onto Quarry road.
23.25	0.3	STOP 2. Abandoned quarries on both sides of road. Park along side of road.