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# Stratigraphy and Sedimentology of the Siegas Formation (Early Llandovery) of Northwestern New Brunswick

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# TRIP C-1

## STRATIGRAPHY AND SEDIMENTOLOGY OF THE SIEGAS FORMATION (EARLY LLANDOVERY) OF NORTHWESTERN NEW BRUNSWICK

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### Introduction

The Siegas area extends across the international border between the United States and Canada at the intersection of the Grand Isle, Stockholm and Van Buren 7 1/2 minute quadrangle maps of the U.S. Geological Survey. Geological work in the area was done between 1967 and 1969 as a Master of Science thesis (Hamilton-Smith, 1969) at the Massachusetts Institute of Technology. Acknowledgements are due to R. R. Shrock, E. Mencher, A. T. Boucot, W. B. N. Berry, J. M. Berdan, R. B. Neuman, J. W. Huddle, D. C. Roy, T. B. Griswold and G. Planansky for assistance, encouragement and guidance during the work. Financial assistance was received from the National Science Foundation and Department of Natural Resources of the Province of New Brunswick.

Rocks of the Siegas area are entirely sedimentary and are between Middle Ordovician and Late Silurian in age. They occur in the tightly folded common limb of the Ashland Synclinorium and the Pennington Mtn. Anticlinorium. The earliest tectonic event recorded in the rocks was the Taconic orogeny, which resulted in the deposition of the Siegas Formation and possible low intensity folding in some older rocks. Bulk deformation of the area occurred after the Late Silurian, probably during the Acadian orogeny.

A simplified geological map of the Siegas area is presented in Figure 1. A homogeneous fold system is recognized which consists of plane, cylindrical, tightly appressed similar folds which are slightly inclined and plunging. Details of outcrop distribution, structural attitudes, etc. may be found in Hamilton-Smith (1970).

### Stratigraphy

The oldest unit exposed in the Siegas area is the Madawaska Lake Formation (Roy et al., 1976) of Late Middle to Late Ordovician in age. The unit is more than 1950 feet thick and is composed of dark grey slate with minor quartzose sandstone. The base of this unit is not exposed. The sandstone is light grey, highly calcareous (25%), quartzose (70%) and fine-grained, with minor amounts of plagioclase, biotite, lithic fragments and sphene. This lithotype occurs in beds from 1/2 inch to 4 feet thick and is usually laminated and cross-laminated. Graptolites collected from one locality in the Siegas area indicate a probable Zone 13 of the Caradoc age (Hamilton-Smith, 1970).

The Carys Mills Formation is between Late or Late Middle Ordovician and earliest Silurian in age and conformably overlies the Madawaska Lake Formation in the Siegas area. The Carys Mills Formation is about 1300 feet thick and is composed of interbedded slate, sandstone and limestone. The characteristic lithotype is dark grey, argillaceous calcilutite (75-90% calcite) which weathers either light bluish grey or light brown. This occurs in beds from 1/2 inch to 16 inches thick and is commonly crosslaminated as modified by convolute lamination. Graded bedding is locally common but obscurely developed, particularly in the finer grained beds. Conodonts and graptolites collected from two localities in the Siegas area indicate a Late Ordovician to Early Silurian (early or middle Llandovery) age (Hamilton-Smith, 1970).

The Siegas Formation of Early Silurian (early Llandovery) age overlies the Carys Mills Formation in the Siegas area with general conformity. Local unconformity due to submarine erosion is established at two localities. The thickness of the Siegas Formation ranges from 800 to 350 feet in the area. The unit is composed of sandstone with minor conglomerate, slate and limestone. Details of facies and lithotypes are discussed below. The sandstone occurs in beds from 1 to 314 inches thick with a variety of sedimentary structures suggestive of depostion from turbidity currents. Modal compositions range from quartz arenites through arkose to lithic wacke. The conglomerate occurs in beds from 2 inches to 27.5 feet thick and consists of limestone clasts up to 36 inches in maximum dimension contained in a lithic wacke matrix. An extensive collection of brachiopods from the Siegas Quarry (EM558) indicates an Early Llandovery age (Ayrton et al., 1969).

The New Sweden Formation (Roy et al., 1976) conformably overlies the Siegas Formation and is between Early Llandovery and Ludlow in age. No fossils are known from this unit in the Siegas area. The New Sweden Formation is about 600 feet thick and consist of grey calcareous slate with minor mamganiferous siltstone.

The Jemtland Formation (Roy et al., 1976) conformably overlies the New Sweden Formation. The unit may be from late Wenlock through early Ludlow in age but in the St. John River valley only Early Ludlow fossil collections are known. No fossils are known from this unit in the Siegas area. The Jemtland Formation is composed of calcareous shale, slate and siltstone with minor sandstone and limestone and is probably more than 2000 feet thick. The top of this unit is not exposed.

## Siegas Formation

The Siegas Formation is of restricted areal extent. To the southeast the unit disappears within 8 miles, probably passing laterally into equivalent beds of the Carys Mills Formation of Early Llandovery age. To the southwest the unit may pass laterally into equivalent beds of the basal Frenchville Formation. Reconnaissance mapping suggests that the Siegas Formation extends at least 7 miles to the north and northwest and possibly as much as 40 miles to the northeast.

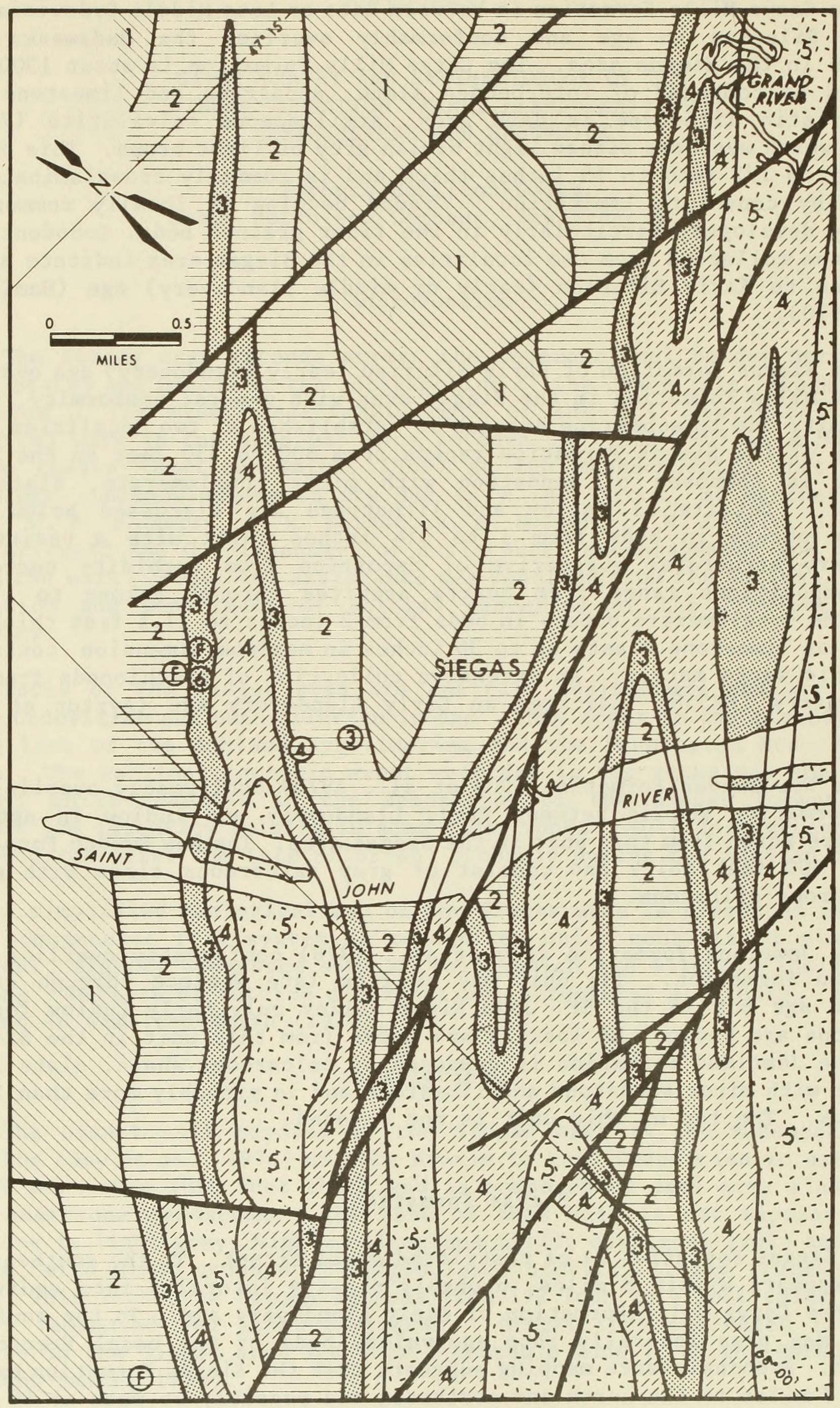
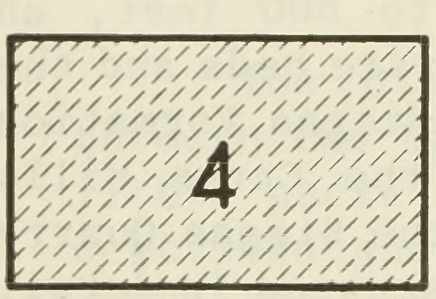
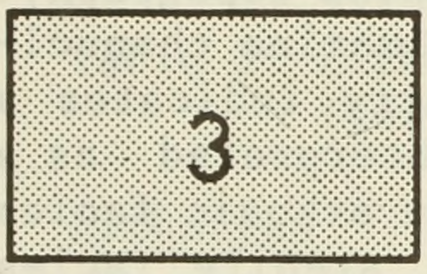



Figure 1: Generalized geological map of the Siegas area, New Brunswick and Maine.

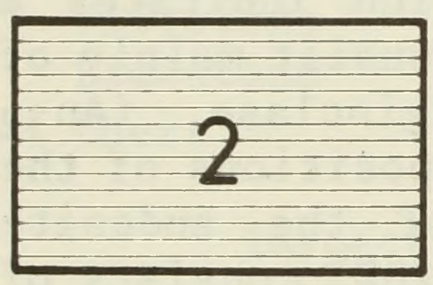

Jemtland Formation: thinly interbedded, fissile, laminated shale, slate and siltstone with minor fine grained light grey sandstone and limestone.



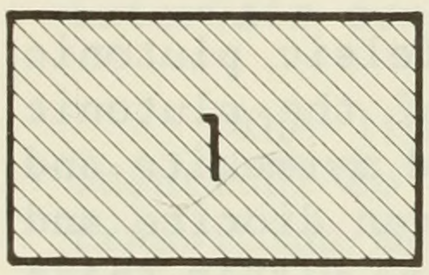

New Sweden Formation: dark to medium grey, laminated, calcareous slate with laminated manganiferous iron-rich siltstone.



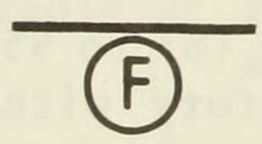

Siegas Formation: interbedded sandstone, slate and conglomerate with minor limestone and chert. Sandstone composition varies from lithic wacke to quartz arenite.



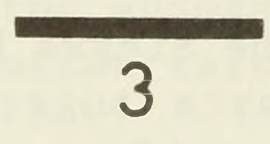

Carys Mills Formation: thinly interbedded dark grey, calcareous slate and limestone. Limestone is dense and micritic and weathers characteristic blue grey and light brown colors.




Madawaska Lake Formation: dark grey, sparsely laminated, non-calcareous slate with minor light grey calcareous fine grained sandstone.




Formation contact
Fossil locality




Fault
Scheduled stop

Within the Siegas area there are significant facies variations within the Siegas Formation. The unit in the western part of the area is 600 to 800 feet thick, characterized mainly by lithic wacke and limestone conglomerate. To the southeast the unit consists of 500 to 600 feet of section, mainly sandstones with a composition ranging from feldspathic arenite to arkosic wacke. To the northeast the Siegas Formation is 350 to 500 feet thick and is composed mainly of quartz arenite, slate and limestone.

The lithic wacke facies displays significant changes from south to north. There is an increase in total section thickness from 500 to 800 feet, an increase in the thickness and abundance of limestone conglomerate beds and the progressive development of an erosional surface between the Siegas Formation and the Carys Mills Formation. As much as 150 feet of the Carys Mills Formation has been eroded in the north part of the facies, at the Siegas Quarry section. The well exposed section in the Siegas Quarry is discussed in detail below.

Facies variations within the Siegas Formation are interpreted as the result of deposition by different processes in a region of complex topography. The lithic wacke facies is understood as the product of a submarine channel-fan system. Paleocurrent information from the Siegas Quarry indicates a derivation from the north. The quartz arenite facies is interpreted as a winnowed shelf deposit resulting mainly from wave action. The arkosic facies is a finer grained deeper water equivalent of the quartz arenite facies deposited on the slope between the shelf and the submarine fan (Hamilton-Smith, 1971a).

The composition of sandstones of the Siegas Formation indicates a specific provenance. Sandstones of the lithic wacke facies consist mainly of andesite fragments and their disintegration products: plagioclase ($An_{32}$ average), quartz and pyroxene. Pyroxene and plagioclase compositions of the sandstones are identical to those of the phenocrysts of the andesite fragments. A distinct minor petrological assemblege (up to 20%) consists of felsic plutonic fragments and their disintegration products: potassium feldspar and quartz. Quartz grains from these two assembleges are morphologically distinct.

Sandstones of the arkosic facies consist mainly of felsic plutonic fragments, potassium feldspar and quartz. The feldspars of the plutonic fragments include orthoclase, perthite, sodic plagioclase and myrmekite and suggest an original source material with a composition between diorite and granite. A small amount of andesite fragments (up to 2%) occurs within these sandstones.

The quartz arenites of the Siegas Formation consist mainly (87 to 95%) of medium grained rounded quartz suggesting a polycyclic history withat least partial derivation from older quartzose sandstones. However, the compositions of the feldspars and lithic fragments of the quartz arenites are identical to those of the arkosic facies, suggesting at least in part a common provenance of felsic plutonic rocks.

The source area of the Siegas Formation is interpreted as a complex local uplift in northwestern New Brunswick consisting of quartzose sandstone, andesite and quartz diorite (Hamilton-Smith, 1971a). This source area would be part of the northern end of the land mass Taconica of Roy (this volume). An analogous association of all three lithotypes is known regionally in the WeeksboroLunksoos Lake anticlinorium (Neuman, 1967).

## Siegas Quarry Section

The Siegas Quarry provides an almost completely exposed section through the Siegas Formation in the thickest and most proximal part of the lithic wacke facies. Each bed in the section was numbered, individually described and assigned to one of the lithotypes: limestone conglomerate, sandstone, siltstone, limestone or chert. A first-order Markov process transition matrix was derived in order to define lithological associations. The matrix elements and other features of the five lithotypes are summarized in Table 1.

Table 1: Lithological features of the Siegas Quarry section (after Hamilton-Smith, 1971b).

| Lithotype | Transition Matrix | | | | | Percent of Thickness | Percent of Beds |
|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | | |
| Conglomerate | S1 | .27 | .68 | .05 | 0 | 0 | 13 | 4 |
| Sandstone | S2 | .07 | .45 | .33 | .09 | .06 | 72 | 34 |
| Siltstone | S3 | .01 | .29 | .32 | .37 | .01 | 12 | 39 |
| Limestone | S4 | .01 | .15 | .68 | .15 | .01 | 2 | 21 |
| Chert | S5 | 0 | .75 | .17 | .08 | 0 | 1 | 2 |

Inspection of the matrix suggests two empirical lithological associations: an exogenic group consisting of limestone conglomerate, sandstone and chert and an endogenic group consisting of limestone and siltstone. In the section at the quarry the lithotypes of the exogenic group occur in three distinct thickly bedded intervals separated by two thinly bedded intervals consisting of lithotypes of the endogenic group.

The limestone lithotype at the Siegas Quarry is an impure micrite identical to the limestone of the underlying Carys Mills Formation. If a transition matrix is derived for the endogenic group and compared to one from the Carys Mills Formation the results are very similar (Table 2).

Table 2: Transition matrices for the endogenic group, Siegas Quarry section and the Carys Mills Formation (after Hamilton-Smith, 1971b).

| Lithotype | Transition Matrix Endegenic Group | | Transition Matrix Carys Mills Formation | |
|---|---|---|---|---|
| | S1 | S2 | S1 | S2 |
| Limestone S1 | .23 | .77 | .15 | .85 |
| Siltstone S2 | .42 | .58 | .55 | .45 |

The interpretation of the transition matrices is that the endogenic group of lithotypes records an extension of the sedimentary conditions of the Carys Mills Formation throughout the time of deposition of the Siegas Formation. The exogenic group records three distinct interruptions of this relatively continuous sedimentation by the deposition of sandstone and limestone conglomerate.

Most of the sandstone beds display the classic characteristic features of turbidite deposition. These features can be well observed on the Siegas Quarry and have been fully described previously (Hamilton-Smith, 1970, 1971b). The distribution of sedimentary structures in the section, particularly in the most significant middle exogenic event, indicates a passage from relatively distal to highly proximal and back to distal depositional conditions. An important feature of the Siegas Quarry section is the presence of thick nongraded sandstone beds and subintervals near the base of graded beds associated with the most proximal phase of turbidite deposition. These nongraded beds and intervals contain scattered limestone clasts up to 24 inches in maximum dimension and are interpreted as grain flow deposits.

The limestone conglomerate beds are associated with the turbidite deposition. They generally consist of limestone and slate clasts up to 24 inches in maximum dimension (60% average) and a sandstone matrix compositionally identical to the lithic wacke of the Siegas Quarry. The limestone and slate clasts are lithologically identical to the lithotypes of the endogenic group and the Carys Mills Formation. The angularity, pull-apart structures and plastic deformation of individual limestone clasts suggest a short history of transportation and semi-consolidation at the time of erosion.

Half of the limestone conglomerate beds are strongly graded and have load casts, erosional surfaces and clast imbrication at the bases of the beds. They occur at the most proximal phase of the middle exogenic event and are interpreted as the product of deposition from turbulent flows with unusually high values of effective density and turbulent intensity. Such values may have been produced by lateral confinement of the flow by a narrow channel.

The other limestone conglomerate beds are not graded and have an internally heterogereous structure. They were probably produced by various forms of mass flow from incoherent slumping to a complex sliding of relatively coherent lenticules over one another with most of the shear stress concentrated near lenticule margins.

The limestone conglomerate beds orginated from a mixture of limestone and slate clasts and unconcolidated sand consisting mainly of andesite fragements. The limestone and slate was probably derived from submarine erosion of the Carys Mills Formation a short distance to the north of the Siegas Quarry. Mixing with the sand may well have occurred by collapse of submarine canyon walls into unconsolidated sand forming the channel floor. Such events may also have initiated the high density for trubulent flows that resulted in the deposition of graded limestone conglomerate beds.

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## Itinerary

Mileage

0 Assembly for trip in Presque Isle, Maine. Starting time 7:45 a.m. Drive north on Route 1 to Van Buren, Maine.

33.0 Enter Van Buren, Maine.

34.0 Cross St. John River into St. Leonard, New Brunswick. Positive identification of citizenship is required for crossing and return. Drive northeast on Route 17 to intersection with TransCanada Highway.

35.3 Turn left onto TransCanada Highway and proceed westbound towards Edmundston.

35.9 Stop 1. Park along shoulder of the road well clear of the highway. Outcrop is in the road cut on both sides of the highway.

New Sweden Formation. The exposure is located on the eastern limb of the Ashland Synclinorium and consists of tightly folded light grey, calcereous laminated slate with laminated manganiferous and iron-rich siltstones.

Return to cars. Procced west on highway.

37.8 Stop 2. Park along shoulder of the road well clear of the highway. Outcrop is in the road cut on both sides of the highway.

Jemtland Formation. The outcrop is to the west of the axis of the Ashland Synclinorium just east of the map-area of Figure 1. The outcrop consists of thinly laminated, fissile, calcareous siltstone, shale and sandstone.

Return to cars. Procced west on highway.

40.5 Stop 3. Park along shoulder of the highway well clear of the road. Outcrop is in the road cut on the north side of the highway.

Carys Mills Formation. The exposure consists of steeply dipping interbedded dark grey calcareous slate and limestone with minor snadstone. The limestone beds weather light blue grey or light brown. The sequence occurs near the base of the Carys Mills Formation.

Walk west along the highway to Stop 4.

Stop 4. The outcrop is in the road cut on the south side of the highway. Cross with due negard for the occasionally very fast traffic.

Carys Mills Formation and Siegas Formation. From east to west the outcrop consists of thinly interbedded dark grey calcareous slate and limestone of the Carys Mills Formation succeeded by massive medium grey lithic sandstone beds of the Siegas Formation. The contact is an erosional one, with clear truncation of laminae in the Carys Mills slate and about a foot of exposed releif.

Return to cars and proceed west along the highway.

43.2 Stop 5. Park along the shoulder of the highway well clear of the road. The outcrop is in the road cut on the north side of the highway.

Madawaska Lake Formation. The exposure is in the core of the Pennington Mountain anticlinorium. The lithology is dark grey non-calcareous sparsely laminated slate with minor thin light grey sandstone beds.

Return to cars and turn around in order to proceed back down the highway to the east.

45.5 Turn left on to access road to the old Highway 2. Immediately turn left again on old Highway 2 and proceed slowly about 150 yards to a gravelled side road. Turn right on the side road and proceed 200 yards to a large open space and park.

Stop 6. The Siegas Quarry. Park in the old processing area at the end of the access road south of the quarry. Walk north to the quarry and proceed to the east end of the exposure at the processing area level.

New Sweden Formation and Siegas Formation. The eastern end of the exposure consists of light grey, calcareous, laminated and locally contorted slate of the New Sweden Formation. The top of the Siegas Formation is defined at the top of the first significant sandstone bed. The contact is conformable. The rest of the exposure consists of almost the entire Siegas Formation in continuous sequence and exposure for about 750 feet of section. The basal beds and the contact with the Cary Mills Formation are obscured but outcrops of the Carys Mills Formation may be observed in the fields immediately to the west of the quarry. The section dips steeply to the northwest and is slightly overturned.

There is an abudance of sedimentary features characteristic of turbidite deposition from both distal to highly proximal phases. Included are graded sandstone and limestone conglomerate beds, massive nongraded beds of sandstone and slump deposits of limestone conglomerate. A wide variety of cross-lamination, convolute lamination and sole features are common.

The Siegas Quarry is the property of Atlas Construction Co. of Fredericton, New Brunswick.