STROMATOPOROIDS AND THE UPPER DEVONIAN ALAMO IMPACT BRECCIA OF SOUTHEASTERN NEVADA

by

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A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Geological Sciences
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2010

ABSTRACT

Eleven species in 10 genera of stromatoporoids were identified from within and below the Alamo Breccia of southeastern Nevada, in an effort to determine the excavation depth of a bolide impact that occurred during the Late Devonian, approximately 382 Ma. The specimens identified in this study are taxa that are also known from Iowa, Canada, and other parts of the world. *Actinostrom*a cf. *A. clathratum, Clathrocoilona* cf. *C. involuta, Stictostroma maclareni*, *Trupetostroma bassleri*, and *Arctostroma contextum* were identified from stromatoporoid-bearing beds located in the Guilmette Formation below the Alamo Breccia. *Atelodictyon* sp. 1, *Hammatstroma albertense*, and *Hermatoporella* sp. 1 were identified from both below and within the Alamo Breccia. The remaining species: *Actinostroma* sp. 1, *Atopostroma distans*, and *Habrostroma turbinatum* were identified from within the Alamo Breccia. Based on the results of this study, a definite depth of penetration cannot be obtained. However, using stromatoporoid biostratigraphy, it is most likely that the bolide impacted no deeper than rocks of Emsian age.

DEDICATION

This thesis is dedicated to my parents, Paul and Min Aul. Thank you for your love and support throughout my graduate studies. It is because of you that this thesis exists.

ACKNOWLEDGMENTS

First and foremost, I would like to thank Carl Stock for serving as my thesis chairman. Carl has been instrumental in the development and completion of this manuscript. Thank you, Carl, for being my friend as well as my mentor. I would also like to thank Ernst Mancini and Amy Weislogel for serving on my thesis committee. Thanks also to Jared Morrow of San Diego State University for serving as my outside committee member. Thank you for your guidance during my field work in Nevada. Your knowledge of the field area was invaluable. Lastly, I would like to thank the W. Gary Hooks Endowed Geology Fund, Geological Sciences Advisory Board, and Department of Geological Sciences at the University of Alabama for the financial support that was provided in order to complete this thesis.

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CHAPTER 1

INTRODUCTION

Stromatoporoids are an extinct class of non-spiculate poriferans that are preserved as fossils by their calcareous skeleton. Stromatoporoids played an important role as one of the primary reef-builders of the early to middle Paleozoic. Similar to modern corals, stromatoporoids thrived in warm tropical reefal environments. Stromatoporoids' closest modern analog is the sclerosponges, which also have a soft body that covers a hard carbonate skeleton (Stearn, 1972). Stromatoporoids vary widely in shape, and can be laminar, bulbous, domical, or branching. Internally, stromatoporoids are composed of skeletal structures more or less parallel and perpendicular to the surface of growth. The structures commonly exhibit a continuous network of repeating pattern. Stromatoporoids also have radial aquiferous canal systems that converge on a center. These canal systems are believed to be similar to the filter-feeding system that can be observed in modern sponges. Stromatoporoids existed in short time ranges and narrow niches, and may be used as both biostratigraphic and paleoenvironmental indicators.

Stromatoporoids first appeared in the Early Ordovician, but were most prolific during the Middle Ordovician through Devonian. Stromatoporoids became extinct at the end of the Late Devonian, and are abundant in Devonian carbonate rocks of North America, Eurasia, and Australia (Stock, 1990). The most abundant orders of stromatoporoids throughout the Devonian are as follows: Syringostromatida, Stromatoporida, Actinostromatida, Stromatoporellida, and Clathrodictyida (Stock, 1990). The Early Devonian was dominated by the following genera: *Syringostroma*, *Atelodictyon*, *Gerronostroma*, *Hermatostroma*, *Simplexodityon* (Stearn, 1979), and *Habrostroma* (Stock, pers. comm. 2010). Stromatoporoids reached their maximum abundances during the Middle Devonian. *Parallelopora*, *Stromatoporella*, *Trupetostroma*, *Anostylostroma*, *Clathrocoilona*, *Stachyodes*, and *Stictostroma* are the genera that were the most prevalent during the Middle-early Late Devonian (Stearn, 1979). During the late Late Devonian *Stylostroma*, *Labechia*, *Pennastroma*, and *Platiferostroma* were the most abundant genera (Stearn, 1979). Stromatoporoid abundances declined before they ultimately became extinct at the end of the Devonian.

Global temperature and sea level are the two main factors that controlled the geographic distribution of stromatoporoids. An increase in global temperature and sea level directly correlates with a wider geographic distribution of stromatoporoids. For example, during the Middle-early Late Devonian a gradual increase in global temperature and sea level resulted in more habitats conducive for stromatoporoid survival (Stock, 2005). Higher global sea levels led to the flooding of continents, thus increasing the amount of habitat suitable for stromatoporoids to sustain life. Stromatoporoids thrived in sub-tropical to tropical waters, and more of these ideal habitats were created by the increasing temperature and sea level. Consequently, the late Late Devonian decrease in global temperature and sea-level led to the eventual extinction of stromatoporoids (Stock, 2005).

The Alamo Breccia of southeastern Nevada was deposited approximately 382 Ma, as the result of a bolide impact onto a shallow carbonate shelf or adjacent deeper water off-shelf-setting. Stromatoporoids were abundant on the pre-impact carbonate shelf, and many were incorporated into the Alamo Breccia, where they form the dominant framework clast type in the Breccia. The geographic distribution of the Alamo Breccia is well documented, and can be observed in several outcrops spanning from southeastern Nevada to western Utah. The Alamo

Breccia was originally divided geographically into three zones and stratigraphically into four units. No visible crater can be examined; therefore, the depth of impact remains a mystery. Warme and Sandberg (1995) thoroughly described the geographic distribution of the Alamo Breccia. Warme and Sandberg (1995) also identified the units of Alamo Breccia and the abundance of stromatoporoids within these units.

Using stromatoporoid biostratigraphy, this study attempts to constrain a depth of penetration of the bolide that resulted in the Alamo Breccia. Stromatoporoids were collected and systematically identified from two localities: Hancock Summit and Golden Gate North (Fig. 1). Sixty specimens were examined resulting in the identification of 11 species in 10 genera.

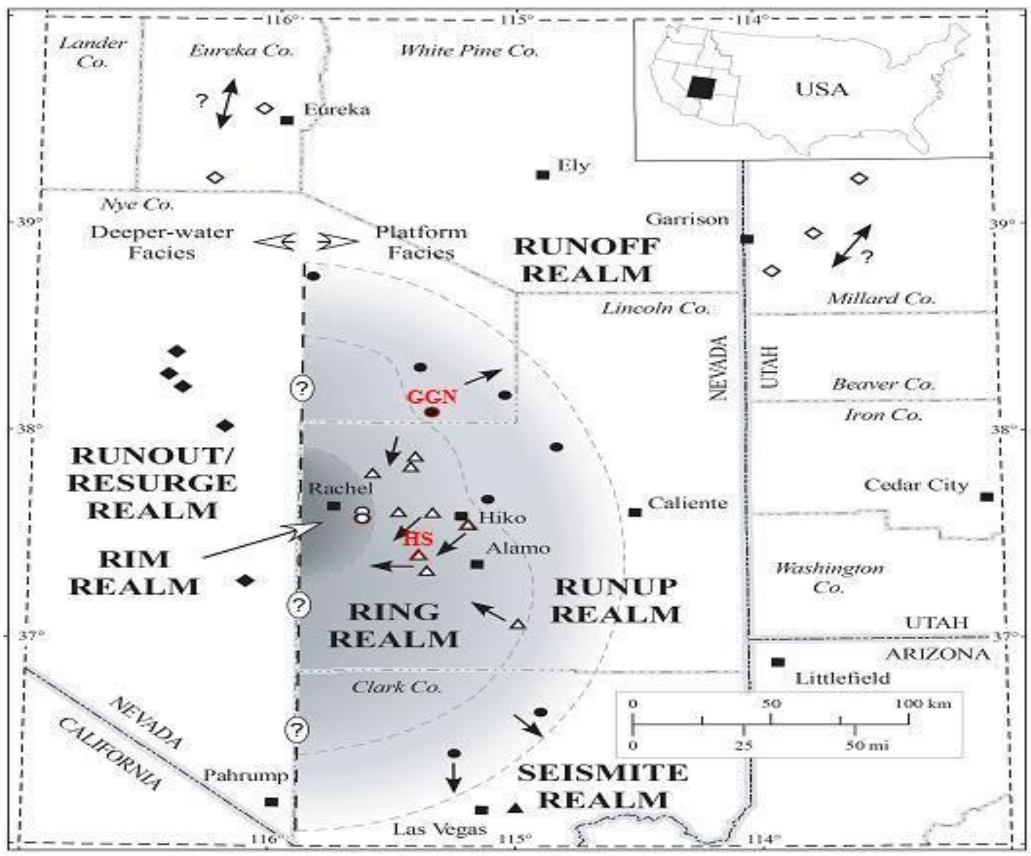

FIGURE *1*—Map showing localities from which specimens were collected. GGN = Golden Gate North; HS = Hancock Summit (modified from Pinto and Warme, 2008).

CHAPTER 2

PREVIOUS WORK

No systematic taxonomic examination of stromatoporoids from the Guilmette Formation has been published prior to this study. Several studies have mentioned the abundance of stromatoporoids as well as their stratigraphic position in the Guilmette Formation (e.g., Ressetar and Herring, 2009). None of these studies includes stromatoporoid taxonomy; however, some have noted the presence of certain genera. Hoggan (1975) identified *Amphipora* as well as *Stachyodes* from the Guilmette Formation of eastern Nevada and western Utah. Dunn (1979) identified the presence of stromatoporoids in the Guilmette Formation at Mount Irish. Warme and Kuehner (1998) noted the abundance of stromatoporoids within the Alamo Breccia, stating that in some localities the stromatoporoids make up more than 50 percent of the rock volume. Sandberg et al. (1997) reported the abundance of bulbous stromatoporoids within the Guilmette Formation, as well as the presence of *Amphipora*. Chamberlain (1999) also identified *Amphipora* as being present in the lower sections of the Guilmette Formation, as well as abundant bulbous and laminar stromatoporoids from the middle to upper sections of the formation. *Amphipora* is easily recognized by its spaghetti-like skeletal morphology, and has therefore been identified in the Guilmette Formation by several researchers.

Although the stromatoporoids of the Guilmette Formation have not until now been properly identified, several systematic studies of stromatoporoids in rocks of similar age located in Iowa, Canada, and Europe have been conducted. However, several of the genera reported in the following studies have since been reclassified. Carl W. Stock is the primary contributor to our knowledge of the Upper Devonian stromatoporids of Iowa. Stock (1973) identified 12 genera and 19 species from the Shell Rock and Lime Creek Formations of Iowa. Stock (1982) identified 10 genera and 11 species from the Mason City Member of the Shell Rock Formation. Melanie J. Smith, a graduate student under the advisement of Carl W. Stock, described 13 genera and 22 species from the Upper Devonian Idlewild Member of the Lithograph City Formation of Iowa.

Most North American Frasnian stromatoporoids have been described from western Canada by Colin W. Stearn. The majority of Stearn's research was conducted in Alberta Province, but Stearn also has studies that identified stromatoporoids located in Saskatchewan, Manitoba, and Northwest Territories. Stearn (1961) identified nine genera and 12 species from the carbonate beds of the Fairholme Group as well as the overlying Alexo and Palliser Formations of the Candian Rocky Mountains of Alberta. Stearn (1962) identified eight genera and 11 species from the Waterways Formation of northeastern Alberta. Stearn (1963) identified eight genera and 14 species from the Beaverhill Lake Formation of the Swan Hills area of Alberta. Stearn (1966b) identified 15 genera and 20 species from the southern Northwest Territories and northern Alberta. Stearn (1975) identified 13 genera and 24 species from the Upper Devonian Ancient Wall Reef Complex of Alberta. Stearn and Shah (1990) identified eight genera and 12 species from the Duperow, Souris River, and Dawson Bay Formations of Saskatchewan. Stearn (1996) identified 16 genera and 24 species from Manitoba.

Although Stearn has been the primary contributor to our knowledge the of Upper Devonian stromatoporoids of Canada, several others have published papers on these stromatoporoids as well. Galloway (1960) identified 11 genera and 23 species from the lower MacKenzie Valley of the Northwest Territories. Klovan (1966) identified 13 genera and 27 species from the Redwater Reef Complex of Alberta. Fischbuch (1969) identified six genera and 11 species from central Alberta.

Few studies in Europe have examined stromatoporoids similar in age to those of the Alamo Breccia. The following papers identified stromatoporoids ranging from Middle to Upper Devonian in age. Lecompte (1951) identified 15 genera and 114 species. Lecompte (1952) identified 10 genera and 71 species. Both of these studies examined stromatoporoids from Belgium. Kazmierczak (1971) identified 17 genera and 50 species of stromatoporoids from the Holy Cross Mountains of Poland. Zukalova (1971) identified 18 genera and 65 species from the Moravian Karst, located in the easternmost regions of the Czech Republic.

No previous examination of stromatoporoid biostratigraphy in the Guilmette Formation has been attempted. However, conodont biostratigraphy has played an important role in dating the Alamo Breccia as well as placing a potential depth of penetration to the impact. Morrow et al., (2005) have identified conodonts from within carbonate lapilli found in the Alamo Breccia that range from the latest Cambrian to the latest Devonian. Based upon this discovery, they have concluded the bolide penetrated into Upper Cambrian rocks at a depth of approximately 1.7 km. The conodonts they identified also suggest the impact occurred in a relatively deep-water slope setting west of the carbonate platform.

CHAPTER 3

STRATIGRAPHY

Lithostratigraphy.— The Guilmette Formation is named for a sequence of interbedded dolomite, limestone, and thin sandstones located in Guilmette Gulch in the Deep Creek Mountains of western Utah. The Middle to Upper Devonian Guilmette Formation represents a shallow-water carbonate platform, exhibiting approximately 150 typical shallowing-upward cycles (Elrick, 1986). The Guilmette Formation is composed of five members in ascending order: the yellow slope-forming member; the carbonate platform facies member; the Alamo Breccia Member; the slope facies member; and the upper Guilmette member. The Guilmette Formation is underlain by the Fox Mountain Formation. The scope of this project included examination of the Fox Mountain Formation, through the Alamo Breccia Member of the Guilmette Formation.

The Fox Mountain Formation is named after Fox Mountain in eastern Nevada. The Fox Mountain Formation extends from the northern Utah to much of southeastern Nevada (Sandberg and Morrow, 2009). The Fox Mountain Formation is commonly the lowermost unit included in the study of the Alamo breccias, and its top is used as a datum for the westward-downcutting base of the impact event (Sandberg et al., 1997). At the type section in Nye County, Nevada (Sandberg et al., 1997), the Fox Mountain Formation is 76.5 m thick, and is comprised of two members. The lower member has been described as a 47.5 m thick brecciated, nonfossilliferous, evaporitic olive-gray micritic limestone (Sandberg et al., 1997). The 29 m thick upper member is composed of olive-gray interbedded open marine crinoidal and coralline packstones and brachiopod packstones (Sandberg et al., 1997). The formation commonly varies in thickness from 75 to 150 m, with a maximum thickness of 200 m in the Confusion Range of western Utah.

The yellow slope-forming member of the Guilmette Formation lies directly above the Fox Mountain Formation, and is considered the basal unit of the Guilmette Formation. The yellow slope-forming member typically ranges in thickness from 30 to 75 m, and is composed of a dolomitic siltstone and a silty dolostone (Sandberg et al., 1997). These siltstones and dolostones distinctly weather to a yellowish-gray slope. The characteristic yellowish-gray slope can be examined in numerous outcrops throughout much of eastern Nevada and western Utah. The yellowish-gray slope is gradually replaced upward by dark-gray limestones of the carbonate-platform facies member (Warme et al., 2008).

The carbonate-platform facies member lies directly below the Alamo Breccia, and is approximately 100 m thick. The carbonate-platform facies member was deposited as a series of shallowing-upward cycles, and is composed of dark–gray limestones that contain abundant bulbous/laminar stromatoporoids in biostromal patch reefs (Sandberg et al., 1997). Various other invertebrate fossils such as corals, ostracodes, and brachiopods can also be found within the carbonate-platform facies member. Upward through the member, the limestones become increasingly lighter in color and dolomitic (Warme et al., 2008).

The Alamo Breccia originated as the result of a shallow to moderately deep marine bolide impact. It was deposited during the course of a few days to weeks, as ensuing debris-flow events and tsunamis reworked the displaced carbonates. The Alamo Breccia can now be examined in over 25 mountain ranges, and it spans nearly 4,000 km^2 throughout much of eastern Nevada (Warme and Sandberg, 1995). The type section of the Alamo Breccia can be found at Hancock Summit N 1/2 SE 1/4 sec. 19, T. 6 S., R. 59 E., Lincoln Co., Nevada, on the Crescent Reservoir quadrangle (Sandberg et al., 1997), one of the two localities included in this thesis. The second locality in this study, Golden Gate North, can be examined at NE 1/4 SE 1/4 SW 1/4 sec. 22, T. 3 N., R. 59 E., Water Gap East 7.5' quadrangle, Nye County, Nevada (Morrow, pers. comm. 2010). The Alamo Breccia can be subdivided in three ways: stratigraphically, geographically, and by depositional environment. The Alamo Breccia is composed of four stratigraphic vertical units (Fig. 2) as well as three geographic lateral zones. The vertical units begin with basal Unit D, and proceed upward in the column to Unit A. Basal Unit D is a calcareous diamictite less than 5 m in thickness, representing fluidized bedrock (Sandberg et al., 1997). Unit C is composed of huge mega-blocks of the carbonate-platform facies member. Some of these blocks are hundreds of meters long and tens of meters high, and contain abundant bulbous/laminar stromatoporoids. Unit B is a chaotic megabreccia composed of blocks of carbonate-platform facies rocks and stromatoporoids in a fine-grained matrix. Unit B contains a wide range of clast sizes. Some clasts are as large as those mentioned in Unit C, whereas others are much smaller. Unit A ranges 1-10 m in thickness, and is composed of multiple fining-upward beds representing turbidite or tsunami deposits. Unit A is visible in two distinct litharenite layers at the type section of the Alamo Breccia. The underlying layer is normally graded, coarse to fine grained, and is about 4 m thick, whereas the other is sandy, very fine grained, normally graded, and about 3 m thick (Sandberg et al., 1997).

The three lateral zones are widely distributed throughout eastern Nevada with Zone 1 being the westernmost edge of distribution and Zones 2 and 3 extending eastward (Figs. 3, 4). The depth of penetration, and the exact location of the crater remain unknown (Fig. 5). Deposits in Zone 1 are the thickest of all of the zones, at approximately 130 m thick, and are composed of thick turbidites overlying a thin debrite (Warme and Sandberg, 1995). Below the debrite, Zone 1 contains semi-autochthonous seismites and allochthonous slide or ejecta blocks that formed as a result of the bolide impact (Pinto and Warme, 2008). Zone 2 contains deposits that are approximately 70 m thick, and includes the type section of the Alamo Breccia. All four vertical units of the Alamo Breccia are present in Zone 2. Zone 3 contains deposits entirely composed of Unit A turbidites or tsunamites, and can be found as far away as western Utah. The depositional environment subdivision will be discussed later.

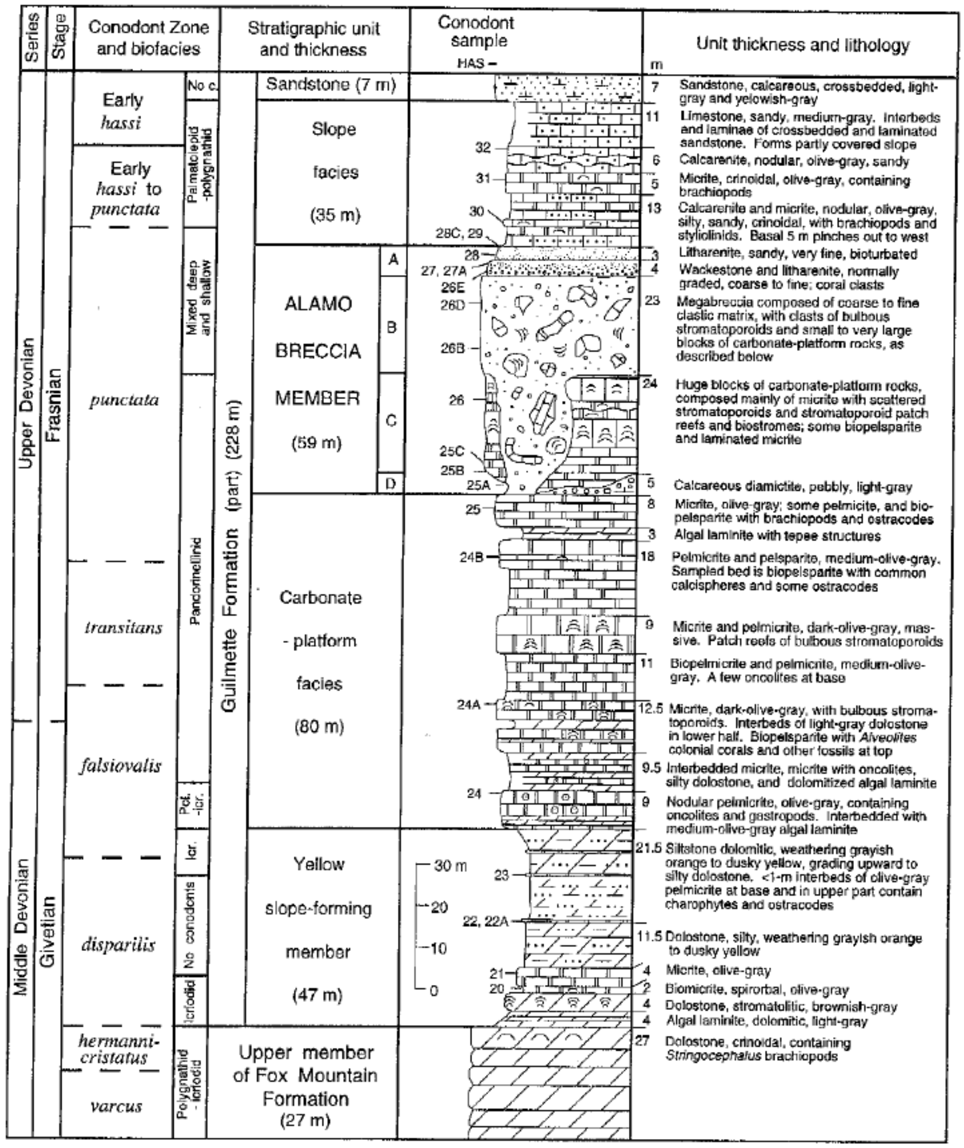

FIGURE *2*—The type section of the Alamo Breccia located at Hancock Summit (from Sandberg et al., 1997, fig. 6, p. 140).

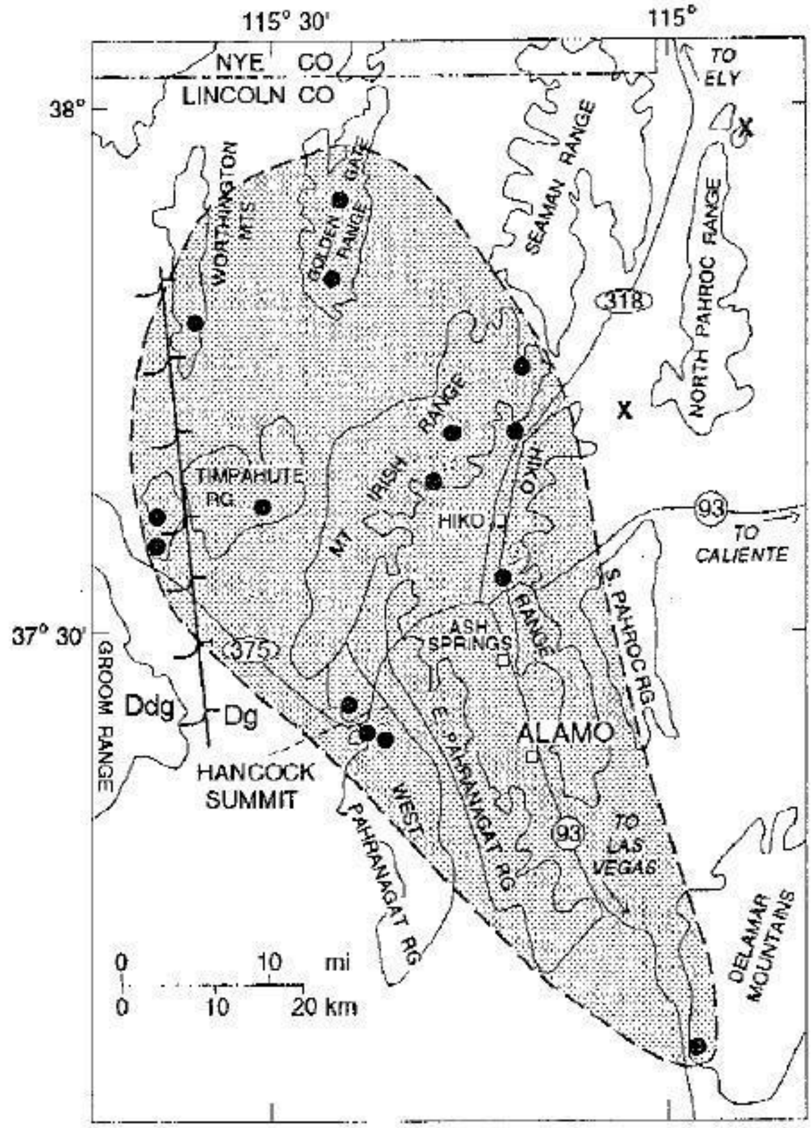

FIGURE *3*—Map showing the distribution of the Alamo Breccia throughout southeastern Nevada. The shaded area is composed of Zones 1 and 2 of the Alamo Breccia. The Xs that are visible in the northeastern corner are located in Zone 3. Ddg = Devils Gate Limestone; Dg = Guilmette Formation; (from Sandberg et al., 1997, fig. 5, p. 139).

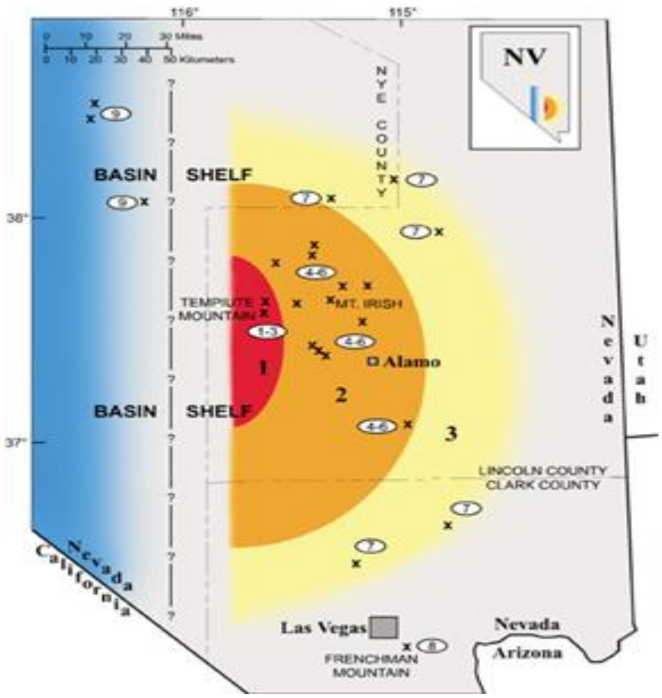

FIGURE *4*—A map showing the distribution of Zones 1, 2, and 3 of the Alamo Breccia. The map also displays the approximate location of a dividing line between the basin and shelf deposits (from Warme, 2004, fig. 1, p. 29).

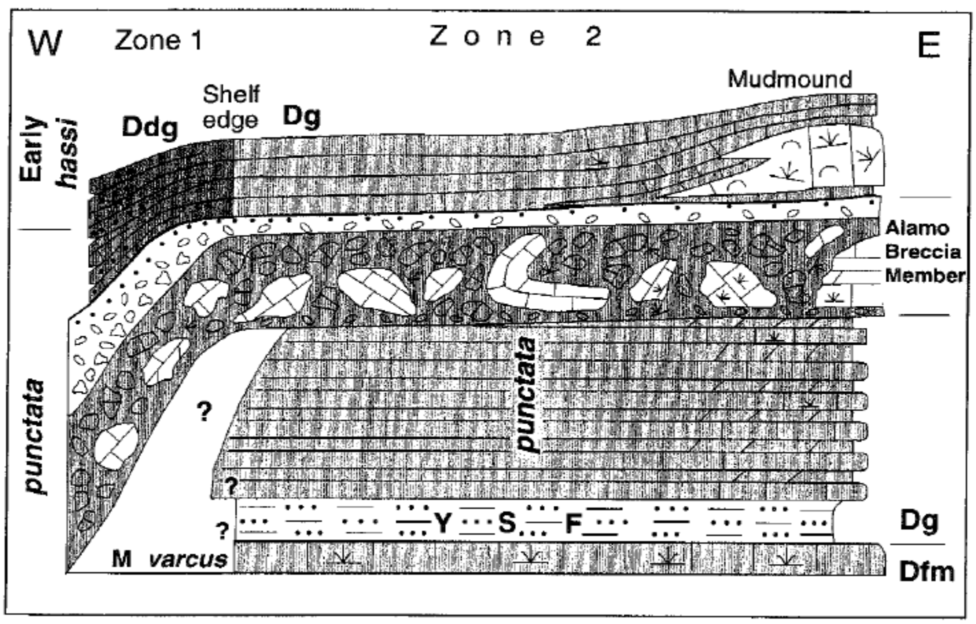

FIGURE *5*—A 30 km cross section of the Alamo Breccia member across Zone 1 and Zone 2. Ddg = Devils Gate Limestone; Dg = Guilmette Formation; YSF = yellow slope-forming member; Dfm = Fox Mountain Formation. The grass-like symbols represent stromatoporoids (from Sandberg et al., 1997, fig. 4, p. 137).

Chronostratigraphy.— Conodont biostratigraphy has been used to date the Guilmette Formation, as well as its confining units. Sandberg and Poole (1977) estimated that the duration of individual Late Devonian conodont zones is approximately 0.5 m.y. Sandberg et al. (1983) used this estimate, employing a technique in which conodont zones were created by counting back from a starting point of zero at the Devonian-Carboniferous boundary. Ziegler and Sandberg (1990) expanded this method, and were able to designate 19 conodont zones dating from the Middle Devonian to the Early Carboniferous. In addition, Sandberg et al. (1997) were able to date 20 major Nevada events (Fig. 6).

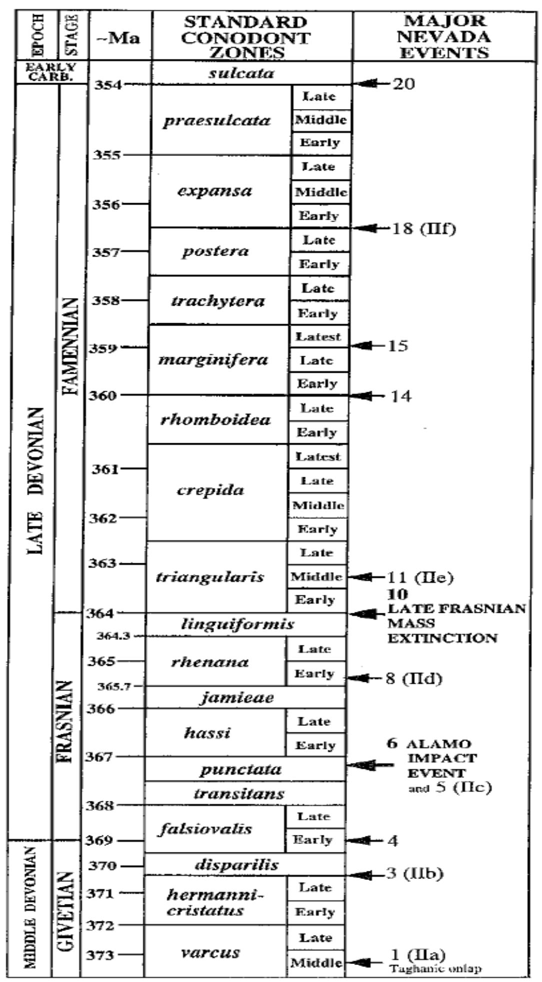

FIGURE *6*—Conodont biochronologic time scale showing the dates of most of the 20 major events in Nevada. Johnson et al. (1985) T-R cycles are shown in parentheses (from Sandberg et al., 1997, fig. 2, p. 132).

The Alamo Impact Event is labeled as the sixth major Nevada Event, and is placed in the *punctata* conodont zone. The Fox Mountain Formation falls within the *varcus* and *hermannicristatus* conodont zones. The boundary between the *hermannicristatus* and *disparilis* conodont zones represents the boundary between the Fox Mountain and Guilmette Formations. The yellow slope-forming member of the lower Guilmette Formation falls almost entirely within the *disparilis* conodont zone. The carbonate-platform facies member of the Guilmette Formation is dominated by both *falsiovalis* and *transitans* conodont zones, with the uppermost layers falling within the *punctata* conodont zone. Morrow et al. (2009) have re-evaluated the conodonts from the lower Guilmette Formation as well as the Alamo Breccia. They used regional sedimentological and conodont biofacies comparisons to locate the onset of the Johnson et al. (1985) transgressive-regressive T-R cycle IIc, which falls within one of the megablocks found within the Alamo Breccia. This T-R cycle is well documented to have begun after the start of the *punctata* conodont zone. Morrow et al. (2009) also analyzed carbon isotopes from the lower Guilmette Formation as well as the Alamo Breccia, and have determined the onset of the *punctata* Event, a global-scale isotopic anomaly, to have occurred after the beginning of the *punctata* conodont zone and after the onset of T-R cycle IIc. This onset date is determined to be approximately 650 k.y. before the Alamo Impact Event.

Depositional history.— The Guilmette Formation is approximately 800 m thick, and is composed of over 150 shallowing-upward sequences. The Guilmette consists almost entirely of carbonates, but in a few places includes beds of quartz arenite sandstone (Biller, 1976). These carbonates were deposited along a westward-deepening carbonate platform. This platform was approximately 1500 km long and 300 km wide, and extended from Alberta, Canada to southern California (Lamaskin and Elrick, 1997). The Transcontinental Arch lay to the east of the carbonate platform deposits of the Guilmette Formation. In the east, rocks of the Guilmette represent a wide range of despositional facies, including carbonate tidal flats, lagoons, and organic buildups. In the west, rocks such as shale, chert, and deep-water limestones were deposited (Elrick, 1986). Between eastern and western depositional facies there is a transitional zone that is dominated by shelf limestones. The sediments of the Guilmette Formation were deposited in normal to hypersaline marine waters. Environments of deposition include the following: a low-to-high energy, shallow water intertidal environment; a moderate energy subtidal environment; and a low energy deeper subtidal environment (Biller, 1976).

The Alamo Impact Event is evidenced by a single, catastrophic-depositional event that lasted mere hours to days. The Alamo Impact Event took place in the Late Devonian approximately 382 Ma, and falls within the middle part of the *punctata* conodont zone. The impact deposits currently span over several thousand square kilometers throughout southeastern Nevada. Early work (e.g., Warme and Sandberg, 1995; Warme, 2004) proposed that the bolide impacted a rimmed, flat-topped carbonate platform, instantaneously displacing a great amount of preexisting carbonate rocks (Fig. 7). Later work (e.g., Morrow et al., 2005; Pinto and Warme, 2008) suggests that the impact site was in a deeper water slope setting located west of the carbonate platform. Huge detached blocks of carbonate platform oscillated and fractured, as an ejecta cloud/blanket pummeled the shallow waters of the adjacent carbonate platform. Below the impact site a system of sandstone-filled dikes and sills was created, as well as a slurry rim around the crater. The slurry rim collapsed inward to form Water Spout 1 and outward to form Tsunami 1. Tsunami 1 propagated throughout the shelf, reworking the ejecta as well as the displaced blocks of carbonate platform rock. Water Spout 1 collapsed outward to form Tsunami 2, and inward to form Water Spout 2. Tsunami 2, like Tsunami 1, propagated throughout the shelf, reworking the carbonate materials. As many as five of these tsunami/water spout sequences could possibly have taken place, represented by the fining-upward and normally graded tsunamites that are present in the Alamo Breccia.

At the conclusion of the event, three distinct zones, and nine types of Alamo Breccia were produced (Warme, 2004). Types 1 and 2 are seismites located below the area of impact. Type 3 includes breccias that eventually flowed in and filled the crater. Type 4 is a layer of fluidized bedrock located directly below the massive blocks of carbonate platform. Type 5 is the chaotic Unit B breccias. Type 6 is the five tsunamites located at the top of the breccias.

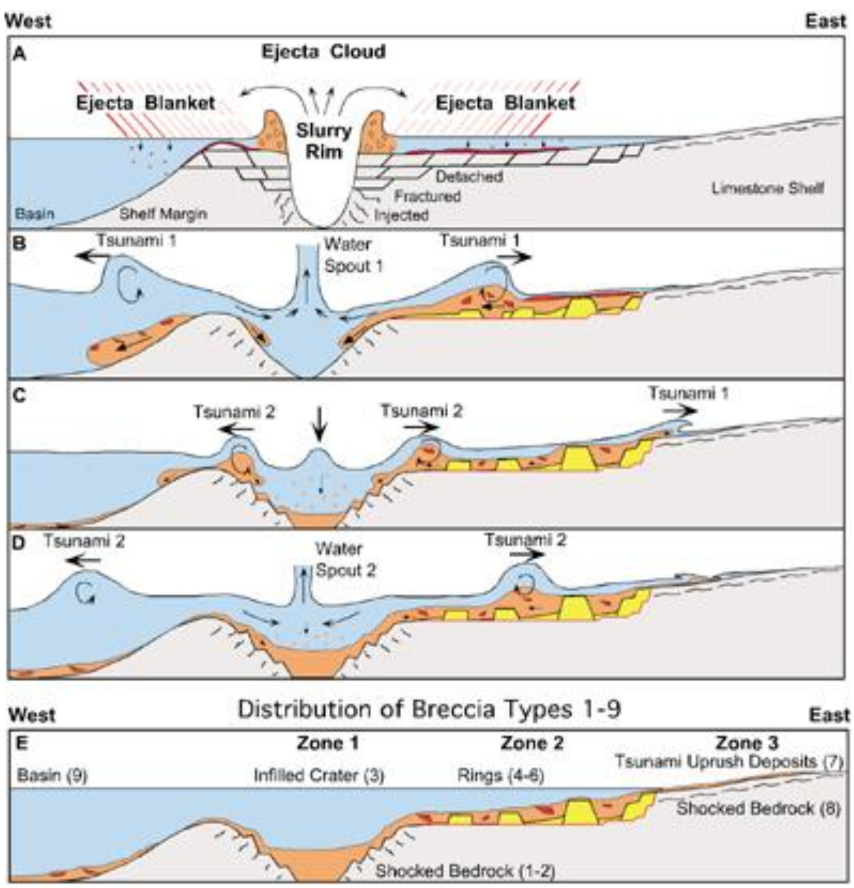

FIGURE *7*—A diagram depicting the formation/distribution of the Alamo Breccia (from Warme, 2004, fig. 2, p. 29).

Type 7 is the tsunami up-rush deposits. Type 8 is seismites located beneath the tsunami uprush deposits, and Type 9 is the westernmost deposits, which flowed into the deep-water basin located offshore from the carbonate platform (Warme, 2004).

Evidence of the Alamo Impact Event exists in the form of carbonate lapilli, shocked quartz grains, and an iridium anomaly. The carbonate lapilli found in the breccias closely resemble volcanic lapilli, and are readily found throughout the breccias. The carbonate composition of the lapilli suggests the target rocks were carbonates, and that the impact did not penetrate into underlying crystalline basement rocks, which underlie the thick sedimentary target sequence (Warme and Kuehner, 1998). The lapilli range from about 2 mm to 3 cm in diameter, and are finely crystalline, exhibiting concentric lamellae around a carbonate clast core. Shocked quartz grains have been found in the matrix of the breccia, in ejecta spherules located within the breccias, and in bedrock located within Zone 1 (Warme and Kuehner, 1998). In thin section, the quartz grains are deformed, and may exhibit up to six directions of shock lamellae. The background iridium levels found in the Guilmette Formation range approximately 2-10 parts per trillion (ppt). The iridium anomaly found in the breccia has been recorded as high as 140 ppt (Warme and Kuehner, 1998). This abundance of iridium is dwarfed in comparison to the level of iridium found at the K-T boundary, which has been recorded to be approximately 10 parts per billion. However, as the breccia almost entirely consists of preexisting carbonate platform, any iridium from a bolide impact would have been greatly diluted (Warme and Kuehner, 1998).

Stromatoporoid biostratigraphy.— Eleven species in 10 genera of stromatoporoids were collected from within and below the Alamo Breccia at two localities. The ranges of the six genera and six species collected from within the Alamo Breccia are in Table 1. Stromatoporoids collected from Unit C of the Alamo Breccia were placed in the same group as the below Alamo

Breccia, based on the fact that Unit C is composed of large pre-existing megablocks of semi-autochthonous carbonate platform.

TABLE *1*— Chronostratigraphic ranges of genera and species collected from the Alamo Breccia.

	DEVONIAN						
	LOWER			MIDDLE		UPPER	
	Lochkovian	Pragian	Emsian	Eifelian	Givetian	Frasnian	Famennian
Atelodictyon sp. 1	X	X	X	X	X	X	X
Hammatostroma albertense						X	
Actinostroma sp.1	X	X	X	X	X	X	
Hermatoporella sp. 1				X	X	X	
Atopostroma distans			X				
Habrostroma turbinatum					X	X	

Five species (*Actinostroma* cf. *A. clathratum*, *Clathrocoilona* cf. *C. involuta*, *Stictostroma maclareni*, *Trupetostroma bassleri*, and *Arctostroma contextum*) were collected exclusively from below the Alamo Breccia. *Actinostroma clathratum* has been reported in Frasnian rocks by Stearn (1966b) and Klovan (1966) in Alberta and by Stock (1982) in Iowa. *Clathrocoilona involuta* has been reported from Givetian rocks by Birkhead (1967) in Missouri and Stock (1982) in the Frasnian of Iowa. *Stictostroma maclareni* has been identified from Frasnian rocks by Stearn (1966b) in the southern Northwest Territories and by Smith (1994) in Iowa. *Trupetostroma bassleri* has been described from Frasnian rocks by Lecompte (1951) in Belgium. Stock (1982) and Smith (1994) have also reported *Trupetostroma bassleri* from Frasnian rocks in Iowa. *Arctostroma contextum* has been identified from Frasnian rocks by Stearn (1963) and Klovan (1966) in Alberta and by Yavorsky (1967) in Russia.

Three species (*Atelodictyon* sp. 1, *Hammatostroma albertense*, and *Hermatoporella* sp. 1) were collected from both below and within the Alamo Breccia. *Atelodictyon* has been identified in Lower, Middle, and Upper Devonian rocks. *Hammatostroma albertense* has been reported in Frasnian rocks by Stearn (1966b) and Klovan (1966) in Alberta and by Stock (1982) in Iowa. *Hermatoporella* has been identified from Middle and Upper Devonian (Frasnian) rocks.

An additional three species (*Actinostroma* sp. 1, *Atopostroma distans* and *Habrostroma turbinatum*) were collected exclusively from the Alamo Breccia. *Actinostroma* has been found in rocks of all stages of the Devonian except the Famennian. *Atopostroma distans* has been identified from Emsian rocks of Canada by Stearn (1983) and Prosh and Stearn (1996). *Habrostroma turbinatum* has been reported in Givetian rocks by Birkhead (1967) in Missouri, and in Frasnian rocks by Smith (1994) in Iowa.

Depth of Bolide Excavation.— Based on stromatoporoid biostratigraphy, it is determined that the bolide must have excavated into at least Emsian age rocks. The Sevy Dolostone (Fig. 8) is the likely source bed of *Atopostroma distans*. It is possible that the bolide excavated to a greater depth, but stromatoporoids may not have been present in the older rock units.

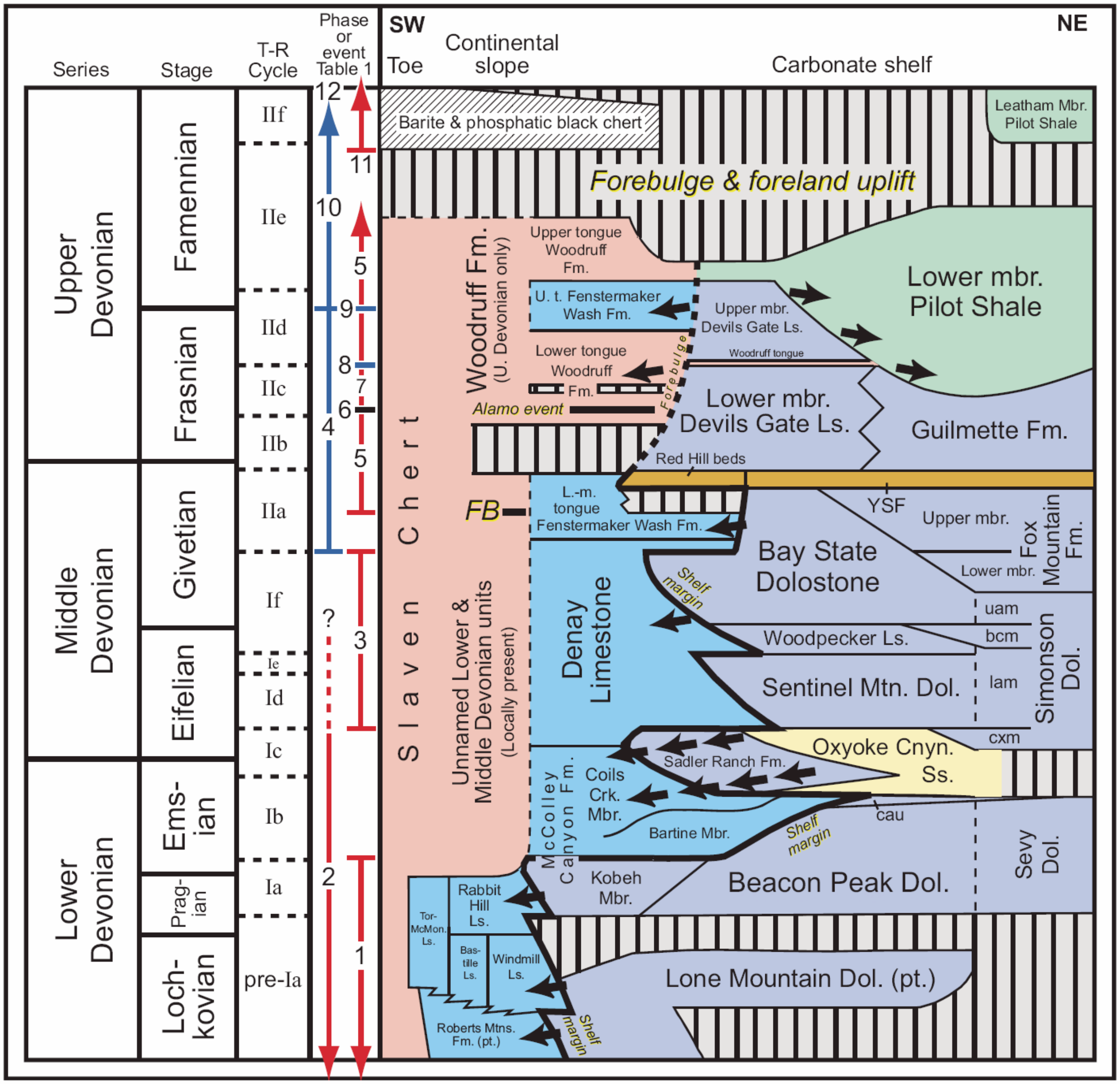

FIGURE *8*—Devonian time-rock transect across central and eastern Nevada. The right side of the figure is characteristic of the field area in southeastern Nevada (from Morrow and Sandberg, 2008, fig. 4, p. 450).

CHAPTER 4

METHODS

Stromatoporoids were collected from two localities, Hancock Summit and Golden Gate North, in southeastern Nevada. These localities lie within the distribution of the Alamo Breccia Member of the Guilmette Formation. Stromatoporoids were collected from within and below the Breccia. Stromatoporoids collected from below the Breccia are located in the lower Guilmette Formation, and were collected from autochthonous, in situ carbonate units.

Whole stromatoporoids as well as thin sections were cataloged using letters and digits. The first two letters designate the locality at which the specimen was collected. The letters are followed by a digit that identifies the bed/unit from which the specimen was collected. The last digit in the catalog represents the specimen number. Labeling for thin sections employed the same cataloging scheme, but with the insertion of an additional letter after the specimen number. The letter A represents a longitudinal thin section and the letter B represents a tangential thin section. For example, HS-1-1A represents the longitudinal thin section of specimen number 1 collected from the B-unit of the Breccia at Hancock Summit.

Stromatoporoid genus and species identifications were determined by examining both the longitudinal and tangential thin sections. Thin sections were prepared from 60 specimens, 22 from Hancock Summit and 38 from Golden Gate North. Measurements such as laminae per mm, pillars per mm, pillar width, laminar thickness, and gallery height were recorded by viewing the logituidinal thin sections. Laminae per mm and pillars per mm were measured center-to-center. For example, if a measurement is begun in the center of one lamina and three whole laminae were included within that measurement the count would therefore be 3.5 laminae per mm. In tangential thin section measurements such as pillar diameter and pillar distance were measured. Once again the measurement of these skeletal structures was recorded by measuring center-to-center.

Both longitudinal and tangential sections are equally important in the process of classification of stromatoporoids. Qualitative properties such as the nature of the pillars/laminae are useful in configuring initial groupings of specimens. When identifying to genus level a qualitative approach is taken. Comparisons of photomicrographs as well as written descriptions in the literature were used to identify these specimens. Stearn et al. (1999) provided the most up-to-date photomicrographs and descriptions of stromatoporoid taxonomy. Beyond these groupings quantitative properties are examined in order to accurately identify the specimens to species. Several counts and measurements were used to identify the specimens. The following longitudinal measurements were recorded from thin section: laminae per mm, pillars per mm, pillar width, laminar thickness, and gallery height. Only two tangential measurements, pillar diameter and pillar distance, were acquired from thin section. These measurements as well as photomicrographs of the specimens were used in comparison with those found in the literature, to accurately identify specimens at the species level.

CHAPTER 5

STROMATOPOROID INTERNAL MORPHOLOGY

Stromatoporoids are an extinct class of non-spiculate poriferans that are preserved as fossils by their carbonate skeletons (Stearn et al., 1999). Externally stromatoporoids are commonly laminar, domical, or bulbous in shape. Occasionally, branching and columnar stromatoporoids may be found. The skeletal structures of stromatoporoids can be divided into five categories: (1) related to skeletal form; (2) parallel to growth surfaces or tangential; (3) normal to growth surfaces or longitudinal; (4) related to the aquiferous filtration system; and (5) related to the microstructure of the laminae and pillars (Stearn et al., 1999). The internal morphology of stromatoporoids is composed of a combination of laminae, pillars, galleries, cyst-plates, and/or amalgamate skeletal material. A thorough investigation of the nature and size of these skeletal structures is vital in determining the genera and species of stromatoporoids.

The two main components of stromatoporoid internal morphology are the laminae and pillars (Fig. 9). Laminae are tangentially extensive skeletal plates that form parallel to the growth surface. Laminae are commonly single-layered, but may also be tripartite. Microlaminae are thin, compact, laterally persistant plates that are commonly part of the skeletal composition of a lamina. Tripartite laminae consist of either a less opaque central zone, a line of cellueles in the central zone, an opaque central zone, or a series of multiple microlaminae (Stearn et al., 1999). Laminae may be pierced by semicircular to circular holes known as foramina (Smith, 1994). In some genera, laminae are composed of colliculi. Colliculi are skeletal rods that join together to form a net parallel to the growth surface. Several laminae bounded above and below by a phase change or growth interruption are known as latilaminae. A latilamina is believed to represent one year of growth.

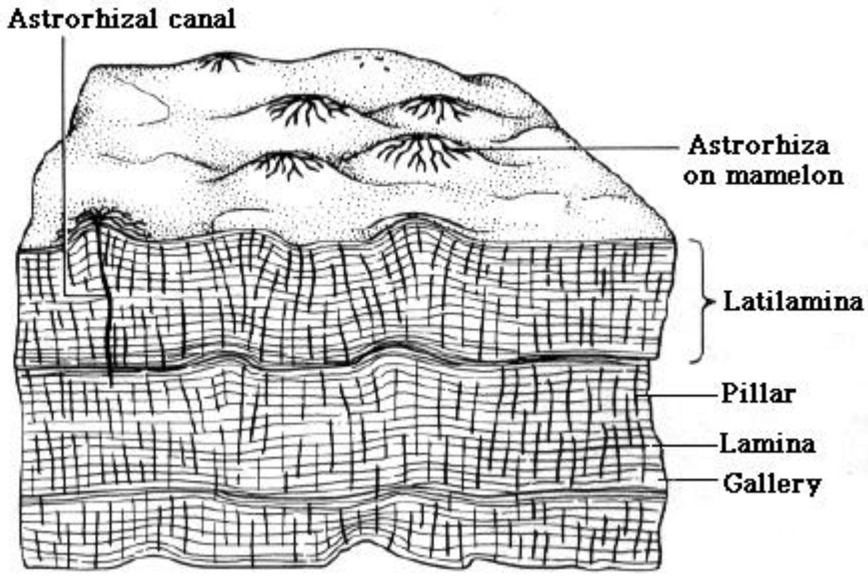

FIGURE *9*— Block diagram of the stromatoporoid *Actinostroma* (from Rigby, 1987, fig. 10, p. 124).

Pillars are longtitudinal skeletal rods that form normal to the growth surface, commonly long and continuous through several laminae and interlaminar spaces (Stearn et al., 1999). Pillars in some cases may be confined to a single interlaminar space. Pillars are commonly columnar, spool-shaped, or upwardly conical in shape. Pillars may also grade into upwardly/downwardly inflected laminae. In some orders, laminae and pillars may be indistinguishable from each other, and form a three-dimentional network of skeletal material known as an amalgamate structure. The alamagamate structure is composed primarily of longitudinal structures known as coenosteles and tangential structures known as coenostromes. Coenosteles are wall-like structures, either meandriform or fused to form a closed continuous network in the amalgamate net (Stearn et al., 1999). Coenostromes are the tangential equivalent of coenosteles.

Laminae and pillars bound interlaminar spaces void of skeletal material, known as galleries (Fig. 9). Galleries are commonly filled with calcite or dolomite cement, but once contained the living tissues of the stromatoporoid (Smith, 1994). Galleries are typically square to rectangular in shape, but may also be circular. Cyst-plates, upwardly convex skeletal plates parallel to the growth surface, are present within many gallery spaces.

Stromatoporoids were suspension feeders that trapped organic material in flagellated chambers that occupied gallery spaces. Externally, stromatoporoids had incurrent pores scattered throughout the living surface (Smith, 1994). Internally, stromatoporoids have a distinct affinity with modern sponges. Stromatoporoids had a distinctive radial aquiferous canal system that converges on a center, much like living coralline sponges in which radial canals are used as a filter-feeding system (Stearn et al., 1999). These canals in stromatoporoids are known as astrorhizal canals (Fig. 9). Astrorhizal canals are part of a stellate, radiating or branching, canal system within the skeleton of the stromatoporoid. In many places astrorhizal canals are partitioned by horizontal skeletal plates called dissepiments (Stearn et al., 1999).

External morphology of the skeleton is useless for identification purposes. The qualitative nature of the internal skeleton (e.g., type of laminae; type of pillars) is used in genus designation, whereas quantitative dimensions of the skeleton (e.g., laminae per mm; pillars per mm; laminar thickness; pillar thickness) are used to identify to species level. Several phase changes exist within stromatoporoids that can affect the accuracy of our measurements. A phase within a stromatoporoid is part of the skeleton that displays a distinct change in growth pattern either longitudinally or tangentially. Stromatoporoids can possess as many as five phases that can be examined in thin section: (1) basal phase; (2) contemporary phase; (3) spacing phase; (4) successive phase; and (5) terminal phase (Stearn et al., 1999). The basal phase is a tangential feature distinguished by structures in the initial growth of the skeleton that differ from those of the mature skeleton. The contemporary phase is a longitudinal feature that is recognized by a unit of skeletal growth of characteristic structure that displaces others tangentially. The spacing phase is any measureable change that occurs in the spacing of laminae, cyst-plates, and cenostromes. The successive phase is a unit of growth distinguished by a longitudinal change in structure within the skeleton (Stearn, et al., 1999). Lastly, the terminal phase is distinguished by the last units of skeletal growth that preserve a distinct change in structure. Due to the nature of these five phases, it is appropriate to record numerous skeletal measurements from a large area. This is done to diminish the influence of these five phases on the outcome of the measurements.

At greater than 40 times magnification a distinct microstructure can be seen in various skeletal structures of the stromatoporoid such as laminae and pillars. Microstructure can be defined as the pattern or configuration of skeletal material that comprises the skeletal structures of the stromatoporoid. There are ten primary types of stromatoporoid microstructure: (1) compact; (2) cellular; (3) melanospheric; (4) fibrous; (5) tubulate; (6) striated; (7) ordinicellular; (8) orthoreticulate; (9) clinoreticulate; and (10) acosmoreticulate (Stearn et al., 1999; Fig. 10). In compact microstructure, the specks in structural elements are evenly distributed. Cellular microstructure resembles compact with the addition of small irregularly distributed clear areas or cellules. Melanospheric microstructure exhibits closely spaced but irregularly distributed opaque areas separated by clear areas. In fibrous microstructure, the specks are in alignment perpendicular to the skeletal structure. Tubulate microstructure has clear areas extending irregularly through the speckled skeletal material of the stromatoporoid. Striated microstructure is identified by its specks, which are concentrated in short, rod-like bodies (Stearn et al., 1999). Ordinicellular microstructure is tripartite, consisting of a central layer of aligned clear areas or cellules as well as two layers of speckled skeletal material that encloses the cellules. The remaining three microstructures (acosmoreticulate, clinoreticulate, and orthoreticulate) are microreticulate in nature. Microreticulate microstructures are structural elements composed of micropillars and microlaminae that form a three-dimensional network of posts and beams (Stearn et al., 1999). Acosmoreticulate microstructure lacks order with its micropillars and microlaminae. Clinoreticulate microstructure has upward and outward curving micropillars. Finally, orthoreticulate microstructure has micropillars that are normal to laminae and microlaminae that are parallel to the laminae.

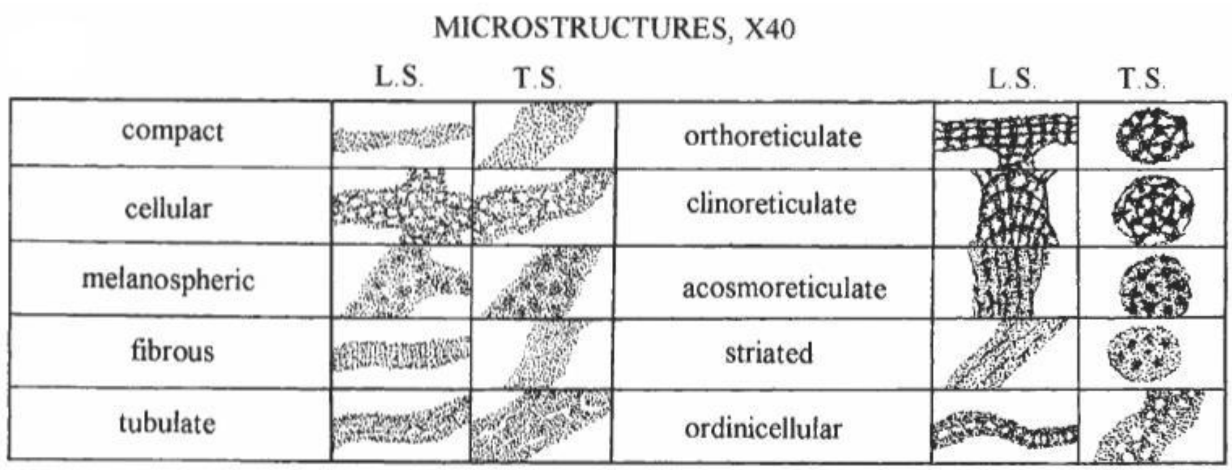

FIGURE *10*— Stromatoporoid microstructures (from Stearn et al., 1999, fig. 2, p. 9). L.S. = longitudinal section; T.S. = tangential section.

CHAPTER 6

SYSTEMATIC PALEONTOLOGY

Phylum PORIFERA Grant, 1836

Class STROMATOPOROIDEA Nicholson and Murie, 1878

Order CLATHRODICTYIDA Bogoyavlenskaya, 1969

Family ATELODICTYIDAE Khalfina, 1968a

Genus ATELODICTYON Lecompte, 1951

Atelodictyon LECOMPTE, 1951, p. 124; GALLOWAY AND ST. JEAN, 1957, p. 122; GALLOWAY, 1957, p. 435; STEARN, 1963, p. 656; 1966a, p. 87; 1966b, p. 46; 1980, p. 894; 1991, p. 618; FLÜGEL AND FLÜGEL-KAHLER, 1968, p. 529; FISCHBUCH, 1969, p. 169; YANG AND DONG, 1979, p. 22; STOCK, 1982, p. 661; MISTIAEN, 1985, p. 54-55; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 69.

Aculatostroma KHALFINA, 1968b, p. 62; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 67; STEARN, 1991, p. 619.

Type species.— *Atelodictyon fallax* Lecompte (1951, p. 125, Pl. 15, figs. 1, 2), Middle Devonian, Eifelian, Dinant Basin, Belgium.

Diagnosis.— Continuous thin laminae; pillars short, bladelike, or irregularly branched, nonsuperposed to superposed, in tangential section rounded to irregular; galleries labyrinthine in tangential section; microstructure compact; astrorhizae rare.

ATELODICTYON sp. 1

Figure 11.1-11.2

Description.— Continuous, undulating, laminae spaced 2.0-4.0 per mm with a mean of 2.9 per mm. Laminae are thin and range in thickness from 0.03 to 0.06 mm with a mean of 0.04 mm. Pillars are in places superposed through several galleries. Where not superposed, pillars appear short and spool-shaped. Pillars are spaced 2.0-4.0 per mm with a mean of 3.1 per mm. Pillar widths range from 0.06 to 0.14 mm with a mean of 0.10 mm. Galleries range from 0.12 to 0.26 in height with a mean of 0.17 mm. Dissepiments are present in many galleries. Microstructure of laminae and pillars is compact. In tangential section, pillars are subcircular to circular and have diameters that range from 0.07 to 0.13 mm with a mean of 0.11 mm. Pillar distances range from 0.15 to 0.22 mm with a mean of 0.18 mm. Astrorhizae are scattered.

Discussion.— Specimens of *Atelodictyon* from this study resemble those described in the literature. Stearn (1966a) described *Ateltodictyon* as having pillars confined to a single interlaminar space, rarely superposed, joined in the laminae by a set of radial processes. He also made note of a hollow depression seen at the top of pillars in tangential section. Stock (1982) described *Atelodictyon* as having nonsuperposed, upwardly expanding pillars. He also identified *Atelodictyon* as having thin laminae, cyst-plates, and a compact microstructure. In tangential view, Stock (1982) also reported a small depression that occurs at the top of pillars in *Atelodictyon*. Smith (1994) reported similar descriptions to those of Stearn (1966a) and Stock (1982). Like the previous two studies, Smith (1994) reported the circular depression common to the pillars of *Atelodictyon*. Specimens in this study compare well to the descriptions and photomicrographs from the literature.

Material and occurrence.— Based on three specimens (HS-1-12, HS-2-1, HS-2-3) collected from within the Alamo Breccia at the Hancock Summit locality. HS-1-12 was collected from Unit B. HS-2-1 and HS-2-3 were collected from Unit C.

Family TIENODICTYIDAE Bogoyavlenskaya, 1965

Genus HAMMATOSTROMA Stearn, 1961

Hammatostroma STEARN, 1961, p. 939, 1966a, p. 92; 1969, p. 757; 1980, p. 896; FLÜGEL AND FLÜGEL-KAHLER, 1968, p. 546; STOCK, 1982, p. 658; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 31.

Intexodictyonella YAVORSKY, 1969, p. 102; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 79.

Type species.— *Hammatostroma albertense* Stearn (1961, p. 939, Pl. 106, figs. 2, 4, text-fig 3), Upper Devonian, Frasnian, Cairn Formation, Sawtooth Mountain, Jasper National Park, Alberta, Canada).

Diagnosis.— Irregular, undulating laminae; pillars irregular, tangled within interlaminar spaces, galleries irregular; transversely fibrous microstructure.

HAMMATOSTROMA ALBERTENSE Stearn, 1961

Figure 11.3-11.4

Hammatostroma albertense STEARN, 1961, p 940, Pl. 106, figs. 2, 4, text-fig 3; 1966b, p. 45, Pl. 13, fig. 3, Pl. 26, fig. 3; 1969, p. 757, Pl. 99, figs. 7, 8; 1975, p. 1650; KLOVAN, 1966, p. 12, Pl. 3, figs. 1a, b; FLÜGEL AND FLÜGEL-KAHLER, 1968, p. 20; STOCK, 1982, p. 658, Pl. 1, figs. 5, 6; STEARN AND SHAH, 1990, p. 1749.

Anostylostroma intermedium KLOVAN, 1966, p. 6, Pl. 1, figs. 2a, b.

Hammatostroma nodosum KLOVAN, 1966, p. 13, Pl. 3, figs. 3a, b.

Tienodictyon albertense (Stearn). KAZMIERCZAK, 1971, p. 75, Pl. 12, figs. 3a, b.

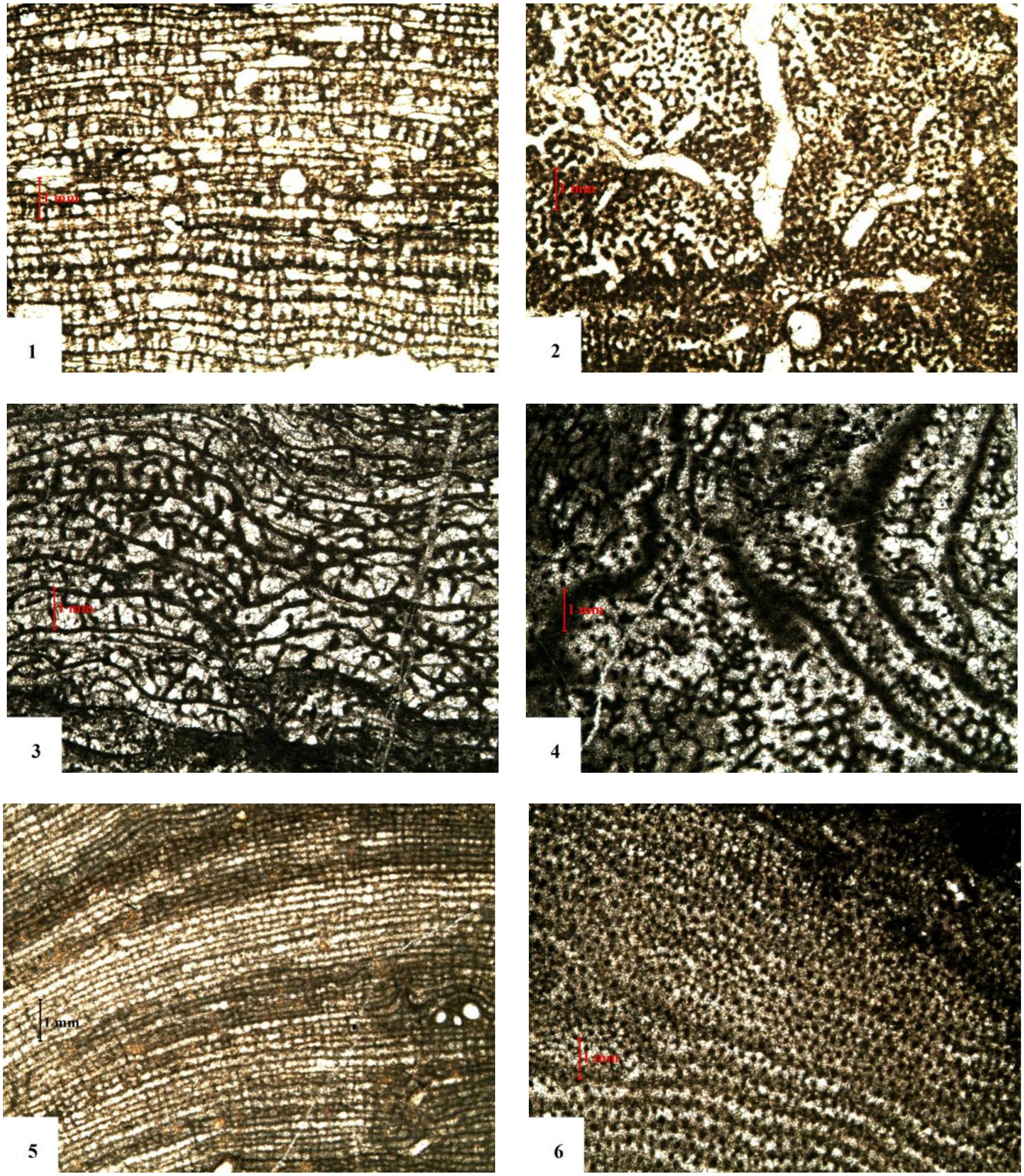

Figure *11*— *Atelodictyon* sp. 1, *Hammatostroma albertense*, *Actinostroma* cf. *A. clathratum*. Magnification 10X. *1-2*, *Atelodictyon* sp. 1. *1*, longitudinal section HS-2-1A; *2*, tangential section HS-2-1B. *3-4*, *Hammatostroma albertense* Stearn, 1961. *3*, longitudinal section GG-5-5A; *4*, tangential section GG-5-5B. *5-6 Actinostroma* cf. *A. clathratum* Nicholson, 1886a. *5*, longitudinal section GG-6-8A; *6*, tangential section GG-6-8B.

Intexodictyon albertense (Stearn). YAVORSKY, 1974, p. 243, Pl. 1, figs. 1a-v.

Description.— Skeletal dimensions are given in Table 2. Laminae are long, thick, and continuous. Laminae are undulating and vary greatly in spacing. Pillars are irregular and form a tangled network within interlaminar spaces. Gallery spaces vary in size and are predominately large and irregular. Cyst-plates are common in gallery spaces. Astrorhizae are absent. Microstructure of laminae and pillars is transversely fibrous.

Discussion.— Specimens of *Hammatostroma albertense* from the Guilmette Formation compare well with those described in the literature. Measurements in this study are consistent with those reported by Stock (1982) and Smith (1994). Both Stock (1982) and Smith (1994) also note the presence of cyst-plates within gallery spaces as well as the absence of astrorhizae.

TABLE *2*—Skeletal dimensions for *Hammatostroma albertense*.

	Hammatostroma albertense Aul (2010)		*Hammatostroma albertense* Stock (1982)		*Hammatostroma albertense* Smith (1994)	
Characteristic	r	x	r	x	r	x
Longitudinal section						
Laminae per mm	1.0-3.0	2.1	1.0-3.0	1.9	2.1-2.2	-
Laminar thickness (mm)	0.03-0.18	0.08	0.05-0.21	0.10	-	0.10
Pillars per mm	1.0-4.0	2.7	1.0-5.0	3.4	2.7-3.0	-
Pillar width (mm)	0.04-0.13	0.09	0.04-0.19	0.10	-	0.10
Gallery height (mm)	0.13-1.50	0.69	0.18-1.27	0.66	0.32-0.33	-
Tangential section						
Pillar diameter (mm)	0.06-0.14	0.10	0.04-0.17	0.10	-	0.12
Pillar distance (mm)	0.19-0.71	0.34	0.13-0.51	0.28	0.18-0.22	0.20

r= range; x= mean

Material and occurrence.— Based on 16 specimens (GG-2-5, GG-3-2, GG-5-1, GG-5-2, GG-5-3, GG-5-4, GG-5-5, GG 5-6, GG-5-7, GG-5-8, GG-6-3, GG-6-4, GG-6-5, GG-6-7, HS-1-

1, HS-1-10) collected from below and within the Alamo Breccia. GG-2-5 was collected from upper Unit B of the Alamo Breccia at the Golden Gate North locality. GG-3-2 was collected from lower Unit B of the Alamo Breccia at the Golden Gate North locality. GG-5-1, GG-5-2, GG-5-3, GG-5-4, GG-5-5, GG 5-6, GG-5-7, GG-5-8, GG-6-3, GG-6-4, GG-6-5, and GG-6-7 were collected near the bottom of the section at the Golden Gate North locality. HS-1-1 and HS-1-10 were collected from Unit B of the Alamo Breccia at the Hancock Summit locality.

Order ACTINOSTROMATIDA Bogoyavlenskaya, 1969

Family ACTINOSTROMATIDAE Nicholson, 1886b

Genus ACTINOSTROMA Nicholson, 1886b

Actinostroma NICHOLSON, 1886b, p. 75; GALLOWAY AND ST. JEAN, 1957, p. 148; GALLOWAY, 1957, p. 437; FLÜGEL, 1959, p. 123; STEARN, 1966a, p. 86; 1980, p. 894; FLÜGEL AND FLÜGEL-KAHLER, 1968, p. 522; STOCK, 1982, p. 669; 1984, p. 774; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 66; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 32.

Rosenia WAAGEN AND WENTZEL, 1887, p. 943

Bullatella BOGOYAVLENSKAYA, 1977, p. 13; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 70.

Auroriina BOGOYAVLENSKAYA, 1977, p. 16; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 70.

Type species.— *Actinostroma clathratum* Nicholson (1886a, p. 226, Pl. 6, figs. 1-3), Middle Devonian, Hebborn, Germany.

Diagnosis.— Vertically continuous, wide pillars connected by horizontally aligned colliculi to form a gridlike pattern; colliculi join pillars to form hexactinellid pattern in tangential section; microstructure compact.

ACTINOSTROMA cf. A. CLATHRATUM Nicholson, 1886a

Figure 11.5-11.6

Actinostroma clathratum NICHOLSON, 1886a, p. 226, Pl. 6, figs. 1-3; FLÜGEL, 1959, p. 129; KLOVAN, 1966, p. 18-19, Pl. 5, figs. 2a, 2b, 3a, 3b; STEARN, 1966b, p. 47-49, Pl. 13, figs. 4, 5, Pl. 16, figs. 3, 4; 1975, p. 1645-1646; STOCK, 1982, p. 669-670, Pl. 3, figs. 5, 6; STEARN AND SHAH, 1990, p. 1749, Pl. 1, fig. 3.

Actinostroma tabulatum LECOMPTE, 1951, p. 102, Pl. 7, fig 2.

Description.— Skeletal dimensions are given in Table 3. Laminae composed of horizontally aligned colliculi. Colliculi are thin and laterally continuous. Pillars are thick and superposed through up to as many as 26 gallery spaces with a maximum length of 4.83 mm. Galleries are square to rectangular in shape and lack the presence of cyst-plates or disspeiments. Microstructure of laminae and pillars is compact. In tangential section, pillars are round and are joined by colliculi to form a distinct hexactinellid pattern.

Discussion.— Specimens of *Actinostroma* cf. *A. clathratum* from the Guilmette Formation closely resemble *Actinostroma clathratum* Nicholson, 1886a, but there is some ambiguity. Measurements reported by Stock (1982) and Smith (1994) are very similar to those reported in this manuscript; however, Stock (1982) reported a mean laminar spacing of 4.8 per mm and Smith (1994) reported a laminar spacing range from 4.1-4.8 per mm. Specimens measured in this study possess a mean laminar spacing (6.1 per mm) significantly greater than those previously reported, therefore these specimens cannot be placed in synonymy with *Actinostroma clathratum* with complete confidence.

Material and occurrence.— Based on two specimens (GG-6-1, GG-6-8) collected near the bottom of the section at the Golden Gate North locality.

ACTINOSTROMA sp.1

Figure 12.1-12.2

Description.— Skeletal dimensions are given in Table 3. Laminae are composed of horizontally aligned colliculi. Pillars are thick and continuous through as many as 18 gallery spaces with a maximum length of 3.78 mm. Microstructure of laminae and pillars is compact. Pillars are round in tangential section, and are joined by colliculi to form a hexactinellid pattern.

Discussion.— Specimens of *Actinostroma* sp. 1 were compared with those of *Actinostroma* cf. *A. clathratum* and *Actinostroma clathratum* of Stock (1982) and Smith (1994). Specimens of *Actinostroma* sp. 1 cannot be placed in synonymy with *Actinostroma* cf. *A. clathratum* due to significant differences in measurements. Laminae of *Actinostroma* cf. *A. clathratum* are spaced at a mean 6.1 per mm. The number of laminae per mm is too many with respect to the mean of 4.3 for *Actinostroma* sp. 1. There are also far too many pillars per mm in *Actinostroma* cf. *A. clathratum*. *Actinostroma* cf. *A. clathratum* has a mean of 4.7 per mm, compared to the mean of 3.3 for *Actinostroma* sp.1. Finally, the pillars of *Actinostroma* sp. 1 are on the average 0.03 mm wider than those of *Actinostroma* cf. *A. clathratum* and travel through far fewer gallery spaces.

Actinostroma sp. 1 does not compare well to specimens of *Actinostroma clathratum* of Stock (1982). Stock (1982) reported more laminae and pillars per mm than *Actinostroma* sp. 1. Stock (1982) also reported significantly thinner pillars that are spaced closer together than those of *Actinostroma* sp. 1. *Actinostroma clathratum* of Smith (1994) has similar counts of laminae and pillars per mm as *Actinostroma* sp. 1. However, like Stock (1982), *Actinostroma clathratum* of Smith (1994) has pillars that are significantly thinner and are spaced closer together than those of *Actinostroma* sp. 1.

TABLE *3*—Skeletal dimensions for Nevada specimens of *Actinostroma*.

	Actinostroma cf. *A. clathratum* Aul (2010)		*Actinostroma* sp. 1 Aul (2010)	
Characteristic	r	x	r	x
Longitudinal section				
Laminae per mm	4.0-7.0	6.1	3.0-5.0	4.3
Laminar thickness (mm)	0.03-0.06	0.05	0.03-0.08	0.04
Pillars per mm	3.0-6.0	4.7	2.0-4.5	3.3
Pillar width (mm)	0.06-0.10	0.08	0.09-0.15	0.11
Gallery height (mm)	0.11-0.29	0.18	0.14-0.25	0.20
Tangential section				
Pillar diameter (mm)	0.06-0.14	0.11	0.08-0.15	0.11
Pillar distance (mm)	0.15-0.31	0.21	0.18-0.29	0.24

r= range; x= mean

Material and occurrence.— Based on five specimens (GG-3-3, HS-1-8, HS-1-9, HS-1-11, and HS-1-13) collected from within the Alamo Breccia. GG-3-3 was collected from lower Unit B of the Alamo Breccia at the Golden Gate North locality. HS-1-8, HS-1-9, HS-1-11, and HS-1-13 were collected from Unit B of the Alamo Breccia at the Hancock Summit locality.

Order STROMATOPORELLIDA Stearn, 1980

Family STROMATOPORELLIDAE Lecompte, 1951

Genus CLATHROCOILONA Yavorsky, 1931

Clathrocoilona YAVORSKY, 1931, p. 1394, 1407; GALLOWAY AND ST. JEAN, 1957, p. 221; GALLOWAY, 1957, p. 451; STEARN, 1966a, p. 98; FLÜGEL AND FLÜGEL-KHALER, 1968, p. 533; STOCK, 1982, p. 670; 1984, p. 776; BOGOYAVLENSKAYA

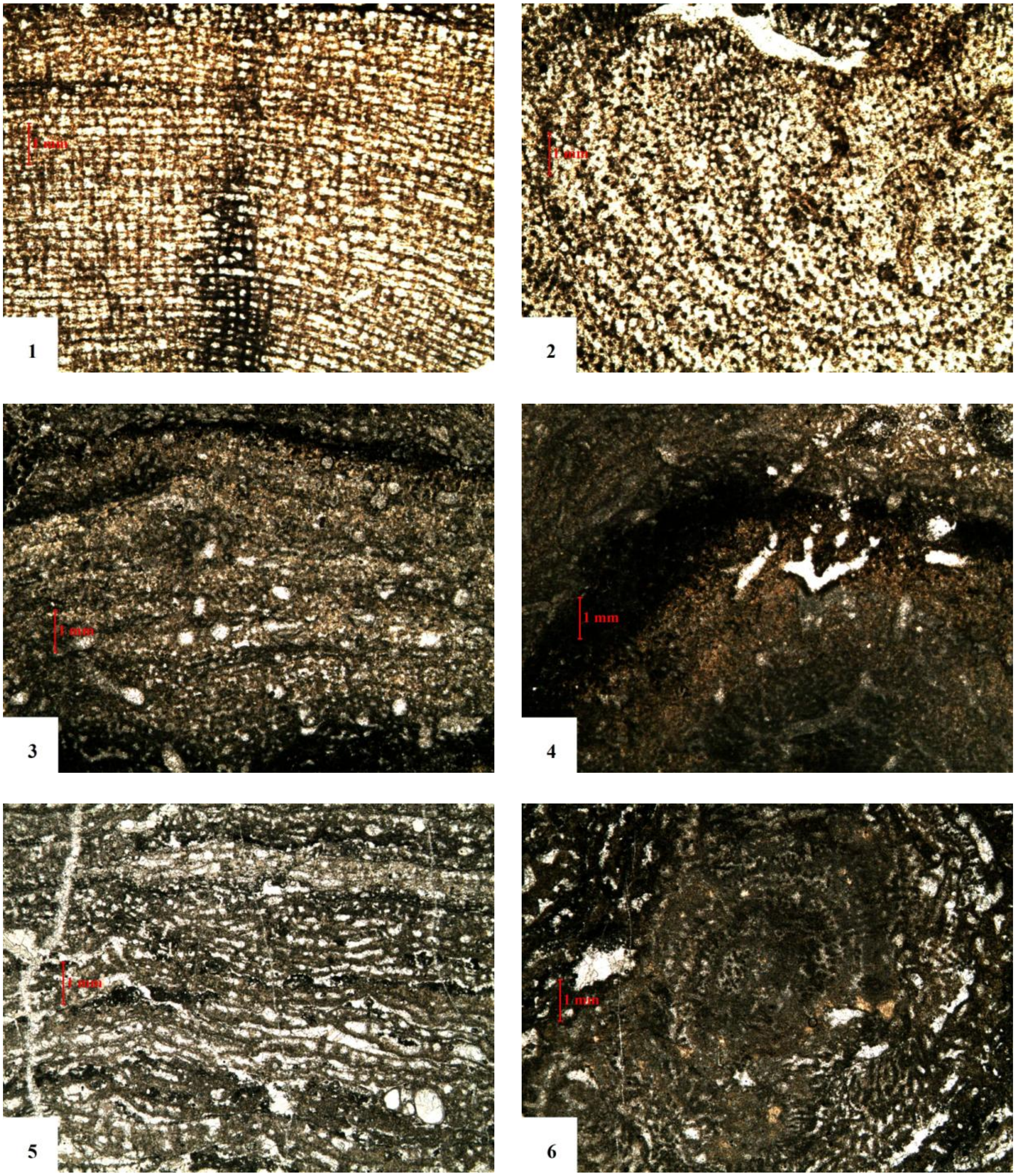

Figure *12*— *Actinostroma* sp. 1, *Clathrocoilona* cf. *C. involuta*, *Stictostroma maclareni*. Magnification 10X. *1-2*, *Actinostroma* sp. 1. *1*, longitudinal section HS-1-9A; *2*, tangential section HS-1-9B. *3-4*, *Clathrocoilona* cf. *C. involuta* Stock, 1982. *3*, longitudinal section GG-4-7A; *4*, tangential section GG-4-7B. *5-6 Stictostroma maclareni* Stearn, 1966b. *5*, longitudinal section GG-6-2A; *6*, tangential section GG-6-2B.

AND KHROMYCH, 1985, p. 71; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 39.

Type species.— *Clathrocoilona abeona* Yavorsky (1931, p. 1395, 1407, Pl. 1, figs. 9-11, Pl. 2, figs. 1-2a), Middle Devonian, Kuznetsk Basin, Russia.

Diagnosis.— Thick, extensive, tripartite lamniae; microstructure odinicelluar, cellular, microreticulate, or tubulate; laminae thicker than galleries high; short, postlike pillars, in many places spool-shaped, not superposed; microstructure compact.

CLATHROCOILONA cf. C. INVOLUTA Stock, 1982

Figure 12.3-12.4

Clathrocoilona subclathrata (Galloway and St. Jean). BIRKHEAD, 1967, p. 80, Pl. 16, figs. 1a, b.

Clathrocoilona involuta STOCK, 1982, p. 672, Pl. 3, figs. 7, 8; Pl. 4, figs. 1-3.

Description.— Skeletal dimensions are given in Table 4. Thick extensive laminae are the primary horizontal skeletal structures. A medial light zone can be observed in many of the laminae. Pillars are short, thick, and non-superposed. Pillars have a compact microstructure. Laminae are thicker than galleries are high.

Discussion.— Specimens of *Clathrocoilona* cf. *C. involuta* from the Guilmette Formation closely resemble *Clathrocoilona involuta* in description and photomicrographs, but vary somewhat in reported measurements. Stock (1982) described thick laminae larger than galleries are high, short spool-shaped pillars, medial laminar light zones, and the presence of astrorhizal canals. Smith (1994) reported similar measurements as Stock (1982). Although Smith (1994) reported mostly similar measurements to those of the specimens in this study, she had pillars that are much thinner than those of this study. The specimens in this study have laminae that are too thin, and pillars that are thicker and spaced too far apart to be included without a doubt in synonymy with *Clathrocoilona involuta*.

TABLE *4*—Skeletal dimensions for *Clathrocoilona involuta*.

	Clathrocoilona cf *C. involuta* Aul (2010)		*Clathrocoilona involuta* Stock (1982)	
Characteristic	r	x	r	x
Longitudinal section				
Laminae per mm	2.0-5.0	3.4	2.0-4.5	3.4
Laminar thickness (mm)	0.06-0.26	0.13	0.08-0.35	0.18
Pillars per mm	2.0-4.0	3.2	2.0-4.0	3.6
Pillar width (mm)	0.08-0.25	0.15	0.06-0.43	0.19
Gallery height (mm)	0.08-0.19	0.12	0.08-0.40	0.15
Tangential section				
Pillar diameter (mm)	0.09-0.20	0.13	0.06-0.25	0.15
Pillar distance (mm)	0.10-0.28	0.20	0.13-0.51	0.28

r= range; x= mean

Material and occurrence.— Based on five specimens (GG-4-1, GG-4-2, GG-4-7, GG-6-6, HS-3-3) collected from below the Alamo Breccia. GG-4-1, GG-4-2, GG-4-7, and GG-6-6 were collected from below the Alamo Breccia at the Golden Gate North locality. HS-3-3 was collected from below the Alamo Breccia at the Hancock Summit locality.

Genus STICTOSTROMA Parks, 1936

Stictostroma PARKS, 1936, p. 77; GALLOWAY AND ST. JEAN, 1957, p. 124; GALLOWAY, 1957, p. 435; ST. JEAN, 1962, p. 186; STEARN, 1966a, p. 96; 1980, p. 897; 1995, p. 24; FLÜGEL AND FLÜGEL-KAHLER, 1968, p. 566; STOCK, 1982, p. 657; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 83; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 42.

Type species.— *Stictostroma goriensis* Stearn (1995, p. 24, figs. 1, 2), Middle Devonian, Eifelian, Gorier, Ontario.

Diagnosis.— Continuous, thick, laminae of ordinicellular microstructure; laminae commonly appear tripartite, fibrous, transversely porous; laminae thinner in width than gallery height; short, spool-shaped pillars not systematically superposed, of cellular microstructure; pillars commonly appear fibrous; astrorhizae may be present .

STICTOSTROMA MACLARENI Stearn, 1966b

Figure 12.5-12.6

Stictostroma maclareni STEARN, 1966b, p. 43-44, Pl. 12, figs. 1-4; Pl. 13, figs. 1, 2; Pl. 26, fig. 2; 1975, p. 1648-1650, Pl. II, figs. 1, 2.

Description.— Skeletal dimensions are given in Table 5. Continuous, thick, laminae that commonly appear to be tripartite in containing a medial light zone surrounded by darker zones on either side. Short, spool-shaped, pillars not systematically superposed. Pillars are compact in microstructure. Galleries are larger in height than laminae are thick. Cyst-plates and astrorhizae are present.

Discussion.— Specimens of *Stictostroma maclareni* from the Guilmette Formation compare well with those described in the literature. Measurements in this study are consistent with those reported by Stearn (1975) and Smith (1994). Smith (1994) thoroughly described *Stictostroma maclareni* as having continuous thick laminae that are thinner than galleries are high. Smith (1994) also described the tripartite nature of the laminae as well as nonsuperposed, spool-shaped pillars exhibiting compact microstructure. Smith (1994) also noted the presence of abundant cyst-plates and astrorhizal canals.

TABLE 5—Skeletal dimensions for *Stictostroma maclareni*.

	Stictostroma maclareni Aul (2010)		*Stictostroma maclareni* Stearn (1975)		*Stictostroma maclareni* Smith (1994)	
Characteristic	r	x	r	x	r	x
Longitudinal section						
Laminae per mm	3.0-5.0	4.0	3.0-4.0	-	4.0-4.8	-
Laminar thickness (mm)	0.04-0.15	0.08	0.08-0.10	-	0.06-0.11	-
Pillars per mm	3.5-4.5	3.7	2.0-3.0	-	3.4-4.1	-
Pillar width (mm)	0.11-0.16	0.13	-	0.08	0.11-0.13	-
Gallery height (mm)	0.13-0.20	0.16	-	-	0.15-0.16	-
Tangential section						
Pillar diameter (mm)	0.10-0.14	0.11	-	-	0.10	-
Pillar distance (mm)	0.09-0.15	0.12	-	-	0.10	-

r= range; x= mean

Material and occurrence.— Based on one specimen (GG-6-2) collected from Stromatoporoid-bearing beds in the Guilmette Formation located below the Alamo Breccia at the Golden Gate North locality.

Family TRUPETOSTROMATIDAE Germovsek, 1954

Genus TRUPETOSTROMA Parks, 1936

Trupetostroma PARKS, 1936, p. 52; GALLOWAY AND ST. JEAN, 1957, p. 158; GALLOWAY, 1957, p. 439; STEARN, 1966a, p. 102; 1980, p. 897; FLÜGEL AND FLÜGEL-KAHLER, 1968, p. 580; KAZMIERCZAK, 1971, p. 111; STOCK, 1982, p. 665; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 92; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 43.

Flexiostroma KHALFINA, 1961, p. 345.

Type species.— *Trupetostroma warreni* Parks (1936, p. 55, Pl. 10, figs. 1, 2), Middle Devonian, Presquile Dolomite, Great Slave Lake, Canada.

Diagnosis.— Continuous, sheetlike, tripartite laminae consisting of medial light or dark zone, in few cases appear to consist of aligned radial rods; systematically superposed, spool-shaped pillars, compact microstructure, cyst-plates common.

TRUPETOSTROMA BASSLERI Lecompte, 1952

Figure 13.1-13.2

Trupetostroma bassleri LECOMPTE, 1952, p. 227, Pl. 37, fig. 3; YAVORSKY, 1965, p. 226, Pl. 4, figs. 7, 8; FLÜGEL AND FLÜGEL-KAHLER, 1968, p. 41; STOCK, 1982, p. 666, Pl. 2, figs. 7, 8; Pl. 3, figs. 1, 2.

Description.— Skeletal dimensions are given in Table 6. Laminae are continuous, thick, and tripartite. Pillars are spool-shaped and systematically superposed. Pillars are superposed through a maximum of six galleries and are compact in microstructure. Cyst-plates are present as well as dichotomously branching astrorhizae. In tangential section, pillars appear irregularly rounded.

Discussion.— Specimens of *Trueptostroma bassleri* from the Guilmette Formation compare well with those described in the literature. Measurements in this study are consistent with those reported by Stock (1982) and Smith (1994). Stock (1982) described *Trupetostroma bassleri* as possessing continuous tripartite laminae, spool-shaped pillars, cyst-plates, and dichotomously branching astrorhizae. In addition, Stock (1982) reported the superposition of pillars through a maximum of five galleries. Smith (1994) also described *Trupetostroma bassleri* as possessing continous gently undulating tripartite laminae, thick spool-shaped pillars, cyst-plates, and astrorhizal canals. Smith (1994) reported the superposition of pillars through a maximum of nine galleries.

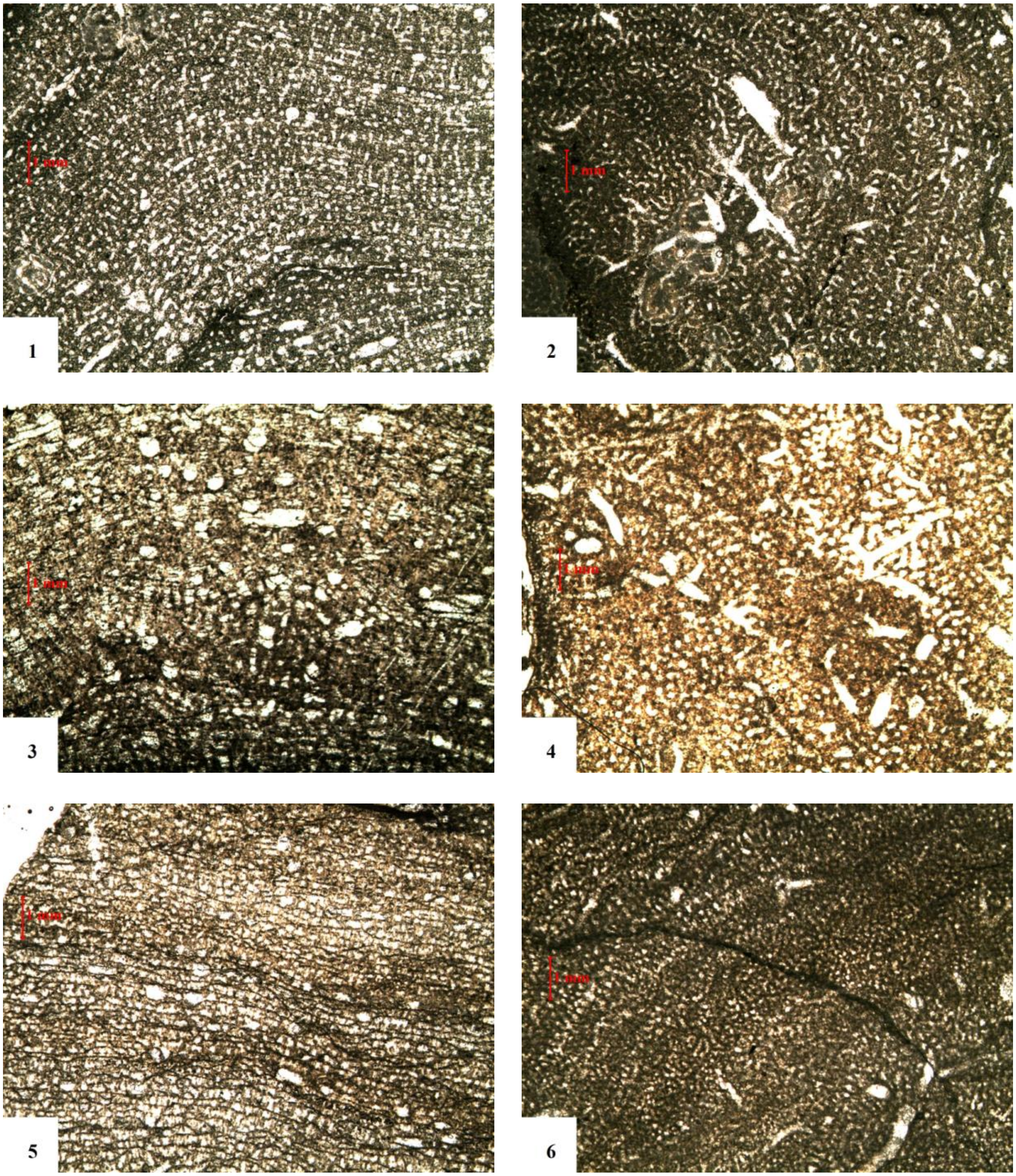

Figure *13*— *Trupetostroma bassleri*, *Hermatoporella* sp. 1, *Arctostroma contextum*. Magnification 10X. *1-2*, *Trupetostroma bassleri* Lecompte, 1952. *1*, longitudinal section HS-3-2A; *2*, tangential section HS-3-2B. *3-4*, *Hermatoporella* sp. 1. *3*, longitudinal section HS-1-14A; *4*, tangential section HS-1-14B. *5-6 Arctostroma contextum* (Stearn, 1963). *5*, longitudinal section HS-3-1A; *6*, tangential section HS-3-1B.

TABLE *6*—Skeletal dimensions for *Trupetostroma bassleri*.

	Trupetostroma bassleri Aul (2010)		*Trupetostroma bassleri* Stock (1982)		*Trupetostroma bassleri* Smith (1994)	
Characteristic	r	x	r	x	r	x
Longitudinal section						
Laminae per mm	2.0-8.0	5.4	2.0-9.0	5.6	4.2-5.5	-
Laminar thickness (mm)	0.03-0.18	0.07	0.02-0.15	0.06	0.08-0.09	-
Pillars per mm	2.0-9.0	4.8	2.0-7.0	4.7	4.2-4.4	-
Pillar width (mm)	0.04-0.13	0.08	0.03-0.19	0.09	0.09-0.12	-
Gallery height (mm)	0.04-0.33	0.15	0.04-0.51	0.15	-	-
Tangential section						
Pillar diameter (mm)	0.03-0.19	0.09	0.03-0.14	0.08	0.08-0.12	-
Pillar distance (mm)	0.09-0.36	0.18	0.08-0.30	0.19	0.09-0.10	-

r= range; x= mean

Material and occurrence.— Based on four specimens (GG-4-4, HS-2-4, HS-3-2, HS-3-4) collected from below and within the Alamo Breccia. GG-4-4 was collected from below the Alamo Breccia at the Golden Gate North locality. HS-2-4 was collected from Unit C of the Alamo Breccia at the Hancock Summit locality. HS-3-2 and HS-3-4 were collected from below the Alamo Breccia at the Hancock Summit locality.

Genus HERMATOPORELLA Khromych, 1969

Hermatoporella KHROMYCH, 1969, p. 34; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 83; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 44.

Type species.— *Trupetostroma maillieuxi* Lecompte (1952, p. 237-239, Pl. 43, figs. 2, 3), Middle Devonian, Bassin De Dinant, Belgium.

Diagnosis.— Coenosteles and microlaminae prominent, forming irregular grid; microlaminae in places locally replaced by dissepiments; coenosteles systematically superposed with peripheral vacuolues in parts of type; in tangential section, form labyrinthine network, rarely present as isolated subcircular masses; microstructure vacuolated, cellular, and compact.

HERMATOPORELLA sp. 1

Fig 13.3-13.4

Description.— Laminae thin and continuous spaced 3.0-7.0 per mm with a mean of 5.1 per mm. Laminae range in thickness from 0.03 to 0.09 mm with a mean of 0.06 mm. In some instances, laminae appear to be replaced by dissepiments. Coenosteles are wide and superposed through many galleries. Coenosteles are spaced 3.0-5.0 per mm with a mean of 3.82 per mm. Coenosteles widths range from 0.07 to 0.15 mm with a mean of 0.10 mm. Galleries are 0.06-0.17 mm in height with a mean of 0.10 mm. In tangential section, coenosteles are subcircular to vermicular. Coenostele diameters range from 0.08 to 0.17 mm with a mean of 0.11 mm. Coenostele distances range from 0.10 to 0.27 mm with a mean of 0.16 mm. Astrorhizae and dissepiments are abundant.

Discussion.— *Hermatoporella* has been commonly misidentified by several researchers. Many researchers have included specimens of *Hermatoporella* in *Trupetostroma*. *Trupetostroma* is identified by its superposed postlike pillars and thick tripartite laminae. *Hermatoporella* resembles *Trupetrostoma* but has thinner laminae and is dominated by the presence of coenosteles. Stearn (2001) made revisions to several misidentified species of *Hermatoporella* from western and arctic Canada. He placed *Trupetostroma hayense* of Stock (1982) in *Hermatoporella.* The specimens in this study are different than those described by Stock (1982). Stock (1982) thoroughly explained the tripartite nature of the laminae of *Trupetostroma hayense*. Species from his study have been placed in synonymy with *Hermatoporella* based on the dominance of coenosteles and microlaminae as well as the nature of these structures in both longitudinal and tangential sections. In addition, the specimens from his study compare well to photomicrographs reported from the literature.

Material and occurrence.— Based on four specimens (GG-2-2, GG-2-8, HS-1-14, HS-2-2) collected from within the Alamo Breccia. GG-2-2 and GG-2-8 were collected from upper Unit B of the Alamo Breccia at the Golden Gate North locality. HS-1-14 was collected from Unit B of the Alamo Breccia at the Hancock Summit locality. HS-2-2 was collected from upper Unit C of the Alamo Breccia at the Hancock Summit locality.

Order STROMATOPORIDA Stearn, 1980

Family FERESTROMATOPORIDAE Khromych, 1969

Genus ARCTOSTROMA Yavorsky, 1967

Arctostroma YAVORSKY, 1967, p. 30; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 69; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 50.

Type species.— *Arctostroma ignotum* Yavorsky (1967, p. 30, Pl. 12, figs. 4-6), Upper Devonian, Frasnian, western foothills of the Urals, Russia.

Diagnosis.— Oblique skeletal structures form cassiculate network in longitudinal section, galleries arch and enclosed at top by skeletal structures; skeletal structures in tangential section commonly labyrinthine, neither coenosteles nor coenestromes notable; microstructure celluar to melanospheric.

ARCTOSTROMA CONTEXTUM (Stearn, 1963)

Fig 13.5-13.6

Ferestromatopora contexta STEARN, 1963, p. 666, Pl. 88, figs. 3-5; 1975, p. 1662.

Ferestromatopora dubia (Lecompte). KLOVAN, 1966, p. 25, Pl. 8, figs. 1a, 1b.

Stromatopora mikkwaensis STEARN, 1966b, p. 55, Pl. 19, fig. 5, Pl. 20, figs. 1-4; 1975, p. 1661.

Description.— Laminae and pillars not easily distinguished. Laminae rarely persistent and traceable throughout the specimens. Laminae appear to be composed of cyst-plates, which connect with adjacent pillars. Post-shaped, nonsuperposed, pillars randomly located throughout the specimens. The skeletal structure is largely amalgamate. Laminae are spaced 3.0-6.0 per mm with a mean of 4.7 per mm. Laminae range in thickness from 0.01 to 0.02 mm with a mean of 0.014 mm. Pillars are spaced 2.0-5.0 per mm with a mean of 4.0 per mm. Pillar widths range from 0.04 to 0.09 mm with a mean of 0.06 mm. Galleries are 0.13-0.20 mm in height with a mean of 0.16 mm. In tangential section, pillar diameters range from 0.08 to 0.15 mm with a mean of 0.11 mm. Pillar distances range from 0.09 to 0.19 mm with a mean of 0.13mm. Astrorhizae are abundant.

Discussion.— *Arctostroma contextum* is highly variable within and between specimens. Few measurements for *Arctostroma contextum* have been reported in the literature. However, the measurements that have been reported compare well with the specimens collected from the Guilmette Formation. Stearn (1963) described *Arctostroma contextum* as having an irregular, very fine network of tissue (i.e., skeletal material) with few traceable laminae and irregular pillars expanding slightly as they meet with laminae. Stearn (1963) also noted the presence of astrorhizal canals and cyst plates. In tangential section, he described a fine lacy network of emergent pillars with laminae that are not readily observable. Stearn (1963) reported the following measurements: laminae spaced 3.0-5.0 per mm, laminar thickness ranging from 0.04 to 0.06 mm, pillars spaced 4.0-4.5 per mm, and pillar widths ranging from 0.04 to 0.07 mm. Klovan (1966) reported the following measurements: laminae spaced 3.8 per mm, laminar thickness ranging from 0.08 to 0.12 mm, pillars spaced 3.0-4.0 per mm, and pillar widths ranging from 0.09 to 0.15 mm. Due to the highly variable nature of the skeletal material in this species, photomicrographs were equally as important as measurements in determining the specimens from the Guilmette Formation as *Arctostroma contextum*.

Material and occurrence.— Based on seven specimens (GG-4-3, GG-4-5, GG-4-6, GG-4-8, GG-4-9, HS-2-5, HS-3-1) collected from below and within the Alamo Breccia. GG-4-3, GG-4-5, GG-4-6, GG-4-8, and GG-4-9 were collected from below the Alamo Breccia at the Golden Gate North locality. HS-2-5 was collected from upper Unit C of the Alamo Breccia at the Hancock Summit locality. HS-3-1 was collected from below the Alamo Breccia at the Hancock Summit locality.

Order SYRINGOSTROMATIDA Bogoyavlenskaya, 1969

Family SYRINGOSTROMATIDAE Lecompte, 1952

Genus ATOPOSTROMA Yang and Dong, 1979

Atopostroma YANG AND DONG, 1979, p. 74, 89; STEARN, 1980, p. 895; 1983, p. 548; 1993, p. 220; DONG, 1983, p. 290; BOGOYAVLENSKAYA AND KHROMYCH, 1985, p. 69; MISTIAEN, 1985, p. 132; WEBBY AND ZHEN, 1993, p. 344; STOCK, 1997, p. 549; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 52.

Type species.— *Atopostroma tuntouense* Yang and Dong (1979, p. 74, Pl. 41, figs. 7, 8), Lower Devonian, Emsian, Yujiange Formation, Guangxi, China.

Diagnosis.— Regular, persistent, laminae formed of one microlamina with skeletal material from pillars spread below; pillars, irregular, superposed through several interlaminar spaces, subcircular in tangential section, spreading upward towards bottom of microlaminae; pillars composed of orthoreticulate to clinoreticulate microstructure.

ATOPOSTROMA DISTANS (Ripper, 1937)

Fig 14.1-14.2

Actinostroma stellulatum var. *distans* RIPPER 1937, p. 12, Pl. 2, figs. 1, 2.

Trupetostroma cf. *T. ideale* Birkhead. STEARN AND MEHROTRA, 1970, p. 16-17, Pl. 5, figs. 1, 2.

Atopostroma tuntouense Yang and Dong. STEARN, 1983, p. 548-549, figs. 4E-H.

Atopostroma distans (Ripper). WEBBY AND ZHEN, 1993, p. 346-348; figs. 11A-D, 12E; WEBBY, STEARN, AND ZHEN, 1993, p. 171, 173, figs. 27F, 28A-D; PROSH AND STEARN, 1996, p. 63, Pl. 18, fig. 5.

Description.— Continuous, thin, laminae composed of a single microlamina. Laminae spaced 3.0-6.0 per mm with a mean of 4.75 per mm. Laminae range in thickness from 0.02 to 0.04 mm with a mean of 0.03 mm. Pillars irregular, spreading laterally towards the base of laminae. Pillars are in many places superposed through several interlaminar spaces. Pillars are spaced 2.0-5.0 per mm with a mean of 3.19 per mm. Pillar widths range from 0.08 to 0.15 mm with a mean of 0.12 mm. Galleries are 0.13-0.30 mm in height with a mean of 0.20 mm. In tangential section, pillars appear subcircular to vermicular, and range in diameter from 0.09 to 0.16 mm with a mean of 0.12 mm. Pillar distances range from 0.15 to 0.28 mm with a mean of 0.21 mm. Astrorhizae are abundant.

Discussion.— The specimens from this study compare well to descriptions and photomicrographs from the literature. Stearn (1983) identified *Atopostroma tuntouense* as having thin, laterally persistent laminae, attached to short superposed pillars that widen as they approach laminae. Stock (1997) described *Atopotostroma* as having subcircular pillars, superposed across many interlaminar spaces, spreading upward, forming a microreticulate

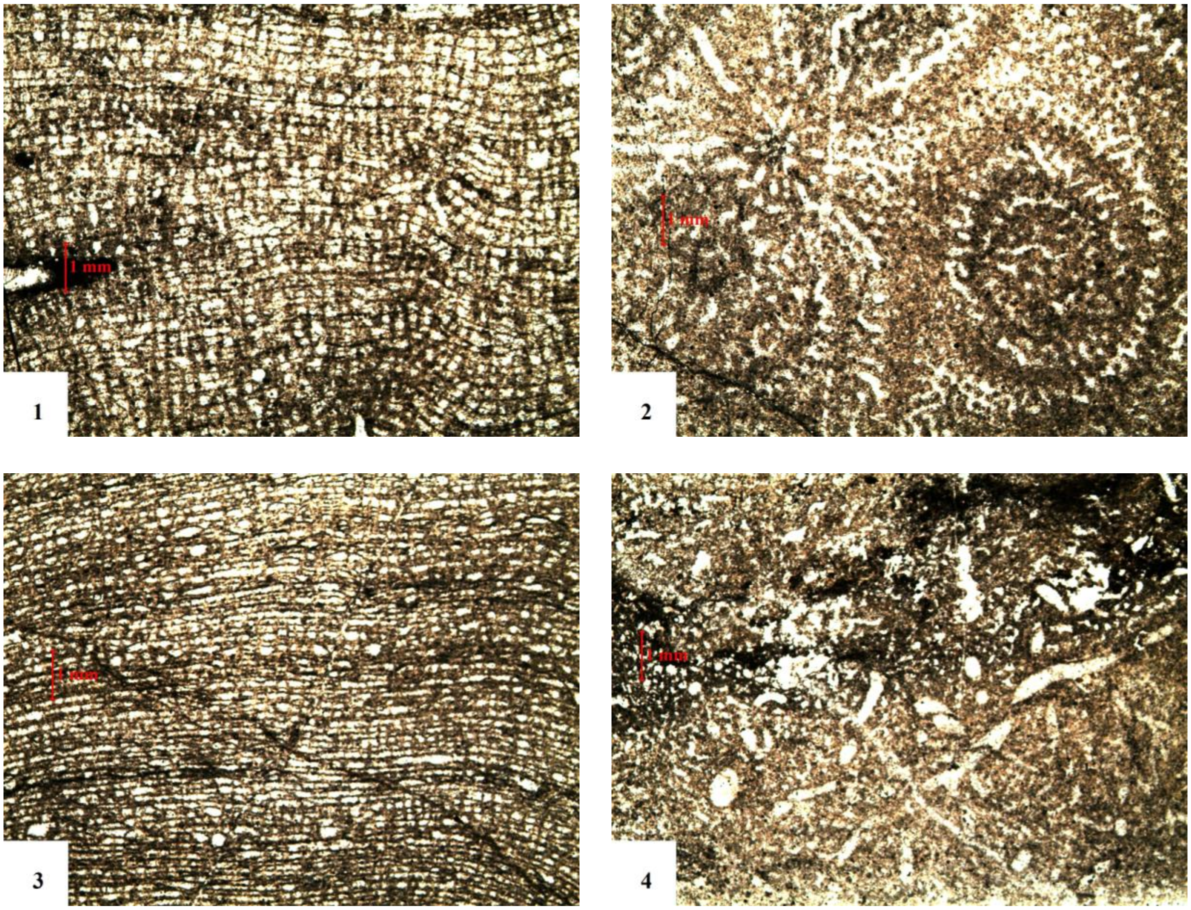

Figure *14*— *Atopostroma distans*, *Habrostroma* cf. *H. turbinatum.* sp. 1.Magnification 10X. *1-2, Atopostroma distans* (Ripper, 1937). *1*, longitudinal section HS-1-2A; *2*, tangential section HS-1-2B. *3-4*, *Habrostroma* cf. *H. turbinatum* (Birkhead, 1967). *3*, longitudinal section HS-1-6A; *4*, tangential section HS-1-6B.

network suspended beneath a single microlamina. Measurements of the specimens from this study are similar to those reported for *Atopostroma tuntouense* by Stearn (1983).

Stearn (1983) reported *Atopostroma tuntouense* as having thin laminae 0.04 mm thick, spaced 4.75 per mm; as well as pillars that are 0.10 mm in width, spaced 4-5 per mm, with diameters of 0.12-0.20 mm. Stearn (1983) failed to report gallery height and pillar distance. Prosh and Stearn (1996) redescribed the specimens from Stearn (1983) and placed them in synonymy with *Atopostroma distans*. Prosh and Stearn (1996) reported the following measurements: laminar spacing of 7 to 11 per 2 mm, pillar spacing of 8 to 10 per 2 mm, and pillar thicknesses of 0.08 to 0.10 mm. Prosh and Stearn (1996, p. 36) noted "Preservation mediocre to moderately well preserved" which could explain the lack of reported measurements.

Material and occurrence.— Based on 10 specimens (GG-2-1, GG-2-4, GG-2-7, GG-2-9, GG-3-5, GG-3-6, GG-3-7, GG-3-8, GG-3-9, HS-1-2) collected from within the Alamo Breccia. GG-2-1, GG-2-4, GG-2-7, and GG-2-9 were collected from upper Unit B of Alamo Breccia at the Golden Gate North locality. GG-3-5, GG-3-6, GG-3-7, GG-3-8, and GG-3-9 were collected from lower Unit B of the Alamo Breccia at the Golden Gate North locality. HS-1-2 was collected from Unit B of the Alamo Breccia at the Hancock Summit locality.

Family COENOSTROMATIDAE Waagen and Wentzel, 1887

Genus HABROSTROMA Fagerstrom, 1982

[?] *Parallelostromella* KOSAREVA *in* IVANIYA AND KOSAREVA, 1968, p. 80.

Habrostroma FAGERSTROM, 1982, p. 11: STEARN, 1990, p. 508; 1993, p. 222; STOCK, 1991, p. 903; 1997, p. 545; WEBBY AND ZHEN, 1993, p. 348; STEARN, WEBBY, NESTOR, AND STOCK, 1999, p. 53.

Type species.— *Stromatopora proxilaminata* Fagerstrom (1961, p. 8, Pl. 1, figs. 4-6), Middle Devonian, Eifelian, Formosa Reef Limestone, Formosa, Ontario, Canada.

Diagnosis.— Continuous laminae composed of microlaminae, connected by regular to irregular pillars; pillars may be superposed; coenostromes and coenosteles may be present where laminae spaced widely apart; coenostromes and laminae typically thinner than galleries high; latilaminae maybe be visible as growth phases; acosmoreticulate microstructure.

HABROSTROMA TURBINATUM (Birkhead, 1967)

Fig 14.3-14.4

Ferestromatopora turbinata BIRKHEAD, 1967, p. 66, Pl. 12, figs. 3a, b.

Description.— Skeletal dimensions are given in Table 7. Laminae are thick, tripartite, and continuous. Laminae appear to be composed of one or more microlaminae. Pillars are thick and spool-shaped. Pillars are predominately non-superposed, but in some areas may be superposed though several galleries. In tangential section, pillars are irregular to vermicular. Astrorhizae are abundant.

Discussion.— The specimens in this study have significant structural similarities to those of *Habrostroma turbinatum*. *Habrostroma turbinatum* has been properly measured and described in two previous studies (Birkhead 1967; Smith 1994). Birkhead (1967) described *Habrostroma turbinatum* as having continuous, thick laminae and irregular pillars superposed through a maximum of three galleries. He also noted the presence of microlaminae. In tangential section, Birkhead (1967) described the vermicular nature of the pillars. Smith (1994) described *Habrostroma turbinatum* as having thick, continuous, tripartite laminae, and wide spool-shaped pillars superposed through two to three galleries. In tangential section, Smith (1994), like Birkhead (1967), described pillars that are irregular to vermicular in nature. The descriptions reported by Birkhead (1967) and Smith (1994) are consistent with those noted in this study, and thus the specimens from Nevada have been placed in synonymy with *Habrostroma turbinatum*.

TABLE 7—Skeletal dimensions for *Habrostroma turbinatum.*

	Habrostroma turbinatum Aul (2010)		*Habrostroma turbinatum* Birkhead (1967)		*Habrostroma turbinatum* Smith (1994)	
Characteristic	r	x	r	x	r	x
Longitudinal section						
Laminae per mm	2.0-7.0	4.9	-	3.5	3.4-4.9	-
Laminar thickness (mm)	0.03-0.08	0.05	0.08-0.23	-	0.09-0.17	-
Pillars per mm	2.0-6.0	4.2	-	-	4.0-4.3	-
Pillar width (mm)	0.04-0.15	0.10	0.08-0.23	-	0.10-0.11	-
Gallery height (mm)	0.08-0.23	0.13	0.08-0.53	-	0.12-0.15	-
Tangential section						
Pillar diameter (mm)	0.04-0.13	0.09	-	0.17	0.08-0.10	-
Pillar distance (mm)	0.10-0.33	0.21	0.10-0.12	-	0.09-0.10	-

r= range; x= mean

Material and occurrence.— Based on two specimens (HS-1-4, HS-1-6) collected from Unit B of the Alamo Breccia at the Hancock Summit locality.

CHAPTER 7

CONCLUSIONS

Eleven species of stromatoporoids in 10 genera were collected from the Upper Devonian (Frasnian) Alamo Breccia of southeastern Nevada. The genera and species collected are Devonian in age and have been found in the United States, Canada, and other parts of the world in rocks of similar age. Five species of stromatoporoids (*Actinostroma* cf. *A. clathratum*, *Clathrocoilona* cf. *C. involuta*, *Stictostroma maclareni*, *Trupetostroma bassleri*, and *Arctostroma contextum*) were identified from below the Alamo Breccia. All of the genera and species identified from below the Alamo Breccia are common in the age of the rocks from which they were collected.

Three species (*Atelodictyon* sp. 1, *Hammatostroma albertense*, and *Hermatoporella* sp. 1) were identified both within and below the Alamo Breccia. *Atelodictyon* has been found in rocks of all stages in the Devonian. *Hammatostroma albertense* is known from rocks that are only Frasnian in age. *Hermatoporella* originated in the Eifelian and survived until the Frasnian. Although *Atelodictyon* has a range that spans throughout all of the Devonian, these specimens are considered to be similar in age to those of *Hammatostroma* and *Hermatoporella,* based on the fact that the same species was collected from below and within the Alamo Breccia.

Three species (*Actinostroma* sp. 1, *Atopostroma distans* and *Habrostroma turbinatum*) were collected from only the Alamo Breccia. *Actinostroma* has a range that spans throughout all of the Devonian. *Atopostroma distans* has been identified in rocks that are Emsian in age. *Habrostroma turbinatum* has been described from rocks that are Givetian-Frasnian in age.

Based on stromatoporoid biostratigraphy, it is concluded that the bolide excavated at least into the Sevy Dolostone. The Sevy Dolostone is Emsian in age and is located approximately 350 m below the Alamo Breccia. The Sevy Dolostone is most likely the source rock from which *Atopostroma distans* was excavated. Three of the genera were not identified to the species level. It is possible that one of these genera, if identified to species level, could be older than Emsian.

REFERENCES

BILLER, E. J. 1976. Stratigraphy and petroleum possibilities of lower Upper Devonian (Frasnian and lower Famennian) strata, southwestern Utah: U.S. Geological Survey Open File Report 76-343, 105 p.

BIRKHEAD, P. K. 1967. Stromatoporoidea of Missouri. Bulletins of American Paleontology, 52:23-110.

BOGOYAVLENSKAYA, O. V. 1965. Rod *Tienodictyon* iz devona Ural. Paleontologicheskii Zhurnal, 1965(3):33-39.

BOGOYAVLENSKAYA, O. V. 1969. K postroyeniyum klassifikatsii stromatoporoidey. Paleontologicheskii Zhurnal, 1969(4):12-27. [Translated in Paleontological Journal, 3:457-471.]

BOGOYAVLENSKAYA, O. V. 1977. Nekotorye stromatoporoidei iz rannedevonskikh otlozhenii vostochnogo sklona Ural, p. 13-30. *In* G. N. Papulov and M. G. Breivel (eds.), Novae materialya po paleontologii Ural. Akademiya Nauk SSSR, Ural'skii nauchnyi tsentr, Institut Geologii i Geokhimi, Trudy, 128.

BOGOYAVLENSKAYA, O. V., AND V. G. KHROMYCH. 1985. Ukazatel' rodov i vidov stromatoporat. Akademiya Nauk SSSR, Sibirskoe Otdelenie, Institut Geologii i Geofiziki, Trudy, 545, 104 p.

CHAMBERLAIN, A. K. 1999. Structure and Devonian stratigraphy of the Timpahute Range, Nevada. Unpublished Ph.d. Dissertation, Colorado School of Mines, Golden, Colorado, 371 p.

DONG, D. Y. 1983. Type and microstructure of the pillars in stromatoporoids. Nanjing Institute of Geology and Palaeontology, Academia Sonica, Bulletin, 6:285-296.

DUNN, M. J. 1979. Depositional history and paleoecology of an Upper Devonian (Frasnian) Bioherm, Mount Irish, Nevada. Binghamton, New York, State University of New York, M.S. thesis, 133 p.

ELRICK, M. 1986. Depositional and diagenetic history of the Devonian Guilmette Formation, Southern Goshute Range, Elko, County, Nevada. Unpublished M.S. thesis, Oregon State University, Corvallis, 119 p.

FAGERSTROM, J. A. 1961. The fauna of the Middle Devonian Formosa Reef Limestone of southwestern Ontario. Journal of Paleontology, 35:1-48.

FAGERSTROM, J. A. 1982. Stromatoporoids of the Detroit River Group and adjacent rocks (Devonian) in the vicinity of the Michigan Basin. Geological Survey of Canada Bulletin, 339, 81 p.

FISCHBUCH, N. R. 1969. Devonian stromatoporoids from central Alberta, Canada. Canadian Journal of Earth Sciences, 6:167-185.

FLÜGEL, E. 1959. Die Gattung *Actinostroma* Nicholson und hire Arden (Stromatoporoidea). Annalen Naturhistorisches Museum in Wien, 63:90-273.

FLÜGEL, E., AND E. FLÜGEL-KAHLER. 1968. Stromatopoidea (Hydrozoa palaeozoica). Fossilium Catalogus, I: Animalia 115, 116, 681 p.

GALLOWAY, J. J. 1957. Structure and classification of the Stromatoporoidea. Bulletins of American Paleontology, 37:345-480.

GALLOWAY, J. J. 1960. Devonian stromatoporoids from the lower Mackenzie Valley of Canada. Journal of Paleontology, 34:620-636.

GALLOWAY, J. J., AND J. ST. JEAN, JR. 1957. Middle Devonian Stromatoporoidea of Indiana, Kentucky, and Ohio. Bulletins of American Paleontology, 37:25-308.

GERMOVSEK, C. 1954. Les Hydrozoa du Jura superieur aux environs de Nova maestro. Slovenska Akademiya Gnostic in Umetnosti, Razred za Prirodoslovne Vede, Razprave, 2:341-386.

GRANT, R. E. 1836. Outlines of comparative anatomy, designed to serve as an introduction to animal physiology and to the principles of classification in zoology, part 1, organs of relation of animal life, part 2, organs of vegetative and inorganic life. H. Bailliere, London, 652 p.

HOGGAN, R. D. 1975. Paleoecology of the Guilmette Formation in eastern Nevada and western Utah. Brigham Young University Geology Studies, 22:141-197.

IVANIYA, V. A., AND E. G. KOSAREVA. 1968. K voprosu o vozraste Kur'inskikh izvestiyakov (sea. Chast' rudnogo Altaya), p. 67-82. *In* V. A. Ivaniya (ed.), Novye materially po stratigrafii i paleontologii nizhnego i srednego paleozoya Zapadnoi Sibiri. Trudy Tomskogo Ordena Trudovogo Krasnogo Znameni Gosudarstvennogo Universiteta im V. V. Kuibysheva, Seriya Geologiceheskaya, 202 p.

JOHNSON, J. G., G. KLAPPER, AND C. A. SANDBERG. 1985. Devonian eustatic fluctuations in Euramerica. Geological Society of America Bulletin, 96:567-587.

KAZMIERCZAK, J. 1971. Morphogenesis and systematics of Devonian Stromatoporoidea from the Holy Cross Mountains, Poland. Palaeontologia Polonica, 26, 146 p.

KHALFINA, V. K. 1961. Order Stromatoporoidea. Silurian System, p. 24-29, 43-56; Devonian System, p. 245-256, 323-349 [in Russian]. *In* L. L. Khalfin (ed.), Paleozoic Biostratigraphy of the Sayan-Altai Mountain Region, 2. Middle Paleozoic. Trudy Sibirskogo Nauchno-Issledovatel'skogo Instituta Geologii, Geofiziki i Mineral'nogo Syr' 20.

KHALFINA, V. K. 1968a. On new genera of stromatoporoids from Devonian deposits of the south-eastern margin of the Kznetsk Basin and Altai. *In* V. A. Ivania (ed.), New Contributions to the Paleontology of the Lower and Middle Paleozoic of Western Siberia. Trudy Tomskogo Ordena Trudovogo Krasnogo Znameni Gosudarstvennogo Universiteta im V. V. Kujbyseva, Seria Geologiceskaa 202:147-152.

KHALFINA, V. K. 1968b. Survey of the stromatoporoid complexes of the Lower and Middle, Devonian of Salair. *In* L. L. Khalfin (ed.), Contributions to the Regional Geology of Siberia, Conference on Devonian Stratigraphy of Siberia, 57-59. Seria Regional'na Geologia, Novosibirsk.

KHROMYCH, V. G. 1969. Stromatoporoidei iz srednedevonskikh otlozhenii Omolonskogo massiva, 29-37 p., *In* A. B. Ivanovski (ed.), Verkhii paleozoi Sibiri i Dal'nego Vostoka. Akademiya Nauk SSSR, Sibirskoe Otdelenie, Instituta Geologii i Geofiziki, Trudy, 68.

KLOVAN, J. E. 1966. Upper Devonian stromatoporoids from the Redwater reef complex, Alberta. Geological Survey of Canada Bulletin, 133:1-32.

LAMASKIN, T. A., AND M. ELRICK. 1997. Sequence stratigraphy of the Middle to Upper Devonian Guilmette Formation, southern Egan and Schell Creek ranges, Nevada, p. 89-112. *In* G. Klapper, M. A. Murphy, and J. A. Talent (eds.), Paleozoic sequence stratigraphy, biostratigraphy, and biogeography: studies in honor of J. Granville ("Jess") Johnson. Geological Society of America, Special Paper 321.

LECOMPTE, M. J. 1951. Les stromatoporoides du Dévonien moyen et supérieur du Bassin de Dinant. Institut Royal des Sciences Naturelles de Belgique, Mémoire 116:1-216.

LECOMPTE, M. J. 1952. Les stromatoporoides du Dévonian moyen et supérieur du Bassin de Dinant. Institut Royal des Sciences Naturelles de Belgique, Mémoire 117:217-359.

MISTIAEN, B. 1985. Phénomènes récifaux dans le Dévonien d'Afghanistan (Montagnes Centrales): Analyse et systématique des Stromatopores. Société Géologique du Nord Publication, 11(2), 381 p.

MORROW, J. R., AND C. A. SANDBERG. 2008. Evolution of Devonian carbonate-shelf Margin, Nevada. Geosphere, 4:445-458.

MORROW, J. R., C. A. SANDBERG, and A. G. HARRIS. 2005. Late Devonian Alamo Impact, Southern Nevada, USA. Evidence of size, marine site, and widespread effects. Geological Society of America Special Paper, 384:259-280.

MORROW, J. R., C. A. SANDBERG, K. MALKOWSKI, AND M. M. JOACHIMSKI. 2009. Carbon isotope chemostratigraphy and precise dating of middle Frasnian (lower Upper Devonian) Alamo Breccia, Nevada, USA. Palaeogeography, Palaeoclimatology, Palaeoecology, 282:105-118.

NICHOLSON, H. A. 1886a. On some new or imperfectly known species of stromatoporoids. Annals and Magazine of Natural History, Series 5, 17:225-239.

NICHOLSON, H. A. 1886b. A monograph of the British stromatoporoids. Palaeontographical Society, London, 39:1-130.

NICHOLSON, H. A., AND J. MURIE. 1878. On the minute structure of *Stromatopora* and its allies. Linnean Society, London, Journal of Zoology, 14:187-246.

PARKS, W. A. 1936. Devonian stromatoporoids of North America, Part 1. University of Toronto Studies, Geological Series, 39, 125 p.

PINTO, J., AND J. WARME. 2008. Alamo Event, Nevada: Crater stratigraphy and impact breccia realms, p. 99-137. *In* K. R. Evans, J. W. Horton Jr., D. T. King Jr., and J. R. Morrow (eds.), The sedimentary record of meteorite impact events. Geological Society of America Special Paper 437.

PROSH, E., AND C. W. STEARN. 1996. Stromatoporoids from the Emsian (Lower Devonian) of Arctic Canada. Bulletins of American Paleontology, 109:5-66.

RESSETAR, R., AND D. M. HERRING. 2009. Distribution of Devonian stromatoporoid buildups in the eastern Basin and Range, *In* B. T. Tripp, K. Krahulec, and J. L. Jordan (eds.), Geology and geological resources and issues of western Utah. Utah Geological Association Publication 38:43-53.

RIGBY, J. K. 1987. Phylum Porifera, p. 116-139. *In* R. S. Boardman, A. H. Cheetham, and A. J. Rowell (eds.), Fossil Invertebrates. Blackwell Scientific Publications, Palo Alto, California.

RIPPER, E. 1937. A note on the occurrence of *Amphipora ramosa* (Phillips) in Western Australia. Royal Society of Western Australia Journal, 23:37-41.

ST. JEAN, J., JR. 1962. Micromorphology of the stromatoporoid genus *Stictostroma* Parks. Journal of Paleontology, 36:185-200.

SANDBERG, C. A., AND E. G. POOLE. 1977. Conodont biostratigraphy and depositional complexes of Upper Devonian cratonic-platform and continental-shelf rocks in the western United States, p. 144-182. *In* M. A. Murphy, W.B.N. Berry, and C.A. Sandberg (eds.), Western North America: Devonian. University of California, Riverside, Campus Museum Contribution, 4.

SANDBERG, C. A., R. C. GUTSCHICK, J. G. JOHNSON, E. G. POOLE, AND W. J. SANDO. 1983. Middle Devonian to Late Mississippian geologic history of the Overthurst Belt region, western United States. Denver, Rocky Mountain Association of Geologists, Geologic Studies of the Cordilleran Thrust Belt, 2:691-719.

SANDBERG, C. A., AND J. R. MORROW. 2009. Recognition of Fox Mountain Formation solves enigmatic Devonian stratigraphy in central and northern Utah. Geological Society of America Abstracts with Programs, 41(6):15.

SANDBERG, C. A., J. R. MORROW, AND J. E. WARME. 1997. Late Devonian Alamo Impact Event, global Kellwasser events, and major eustatic events, eastern Great Basin, Nevada and Utah. Brigham Young University Geology Studies, 42:129-160.

SMITH, M. J. 1994. Upper Devonian stromatoporoids from the Idlewild Member of the Lithograph City Formation of north-central Iowa. Unpublished M.S. Thesis, University of Alabama, Tuscaloosa, Alabama, 149 p.

STEARN, C. W. 1961. Devonian stromatoporoids from the Canadian Rocky Mountains. Journal of Paleontology, 35:932-948.

STEARN, C.W. 1962. Stromatoporoid fauna of the Waterways Formation (Devonian) of northeastern Alberta. Geological Survey of Canada Bulletin, 92:1-22.

STEARN, C. W. 1963. Some stromatoporoids from the Beaverhill Lake Formation (Devonian) of the Swan Hills area, Alberta. Journal of Paleontology, 37:651-668.

STEARN, C. W. 1966a. The microstructure of stromatoporoids. Palaeontology, 9:74-124.

STEARN, C. W. 1966b. Upper Devonian stromatoporoids from southern Northwest Territories and northern Alberta. Geological Survey of Canada Bulletin, 133:35-68.

STEARN, C. W. 1969. The stromatoporoid genera *Tienodictyon*, *Intexodictyon*, *Hammatostroma*, and *Plexodictyon*. Journal of Paleontology, 43:753-766.

STEARN, C. W. 1972. The relationship of the stromatoporoids to the sclerosponges. Lethaia, 5:369-388.

STEARN, C. W. 1975. Stromatoporoid assemblages, Ancient Wall reef complex (Devonian), Alberta. Canadian Journal of Earth Sciences, 12:1631-1667 .

STEARN, C. W. 1979. Biostratigraphy of Devonian stromatoporoids. Special Papers in Paleontology, 23:229-232.

STEARN, C. W. 1980. Classification of the Paleozoic stromatoporoids. Journal of Paleontology, 54:881-902.

STEARN, C. W. 1983. Stromatoporoids from the Blue Ford Formation (Lower Devonian) of Ellesmere Island, Artic Canada. Journal of Paleontology 57:539-559.

STEARN, C. W. 1990. Stromatoporoids from the allochthonous reef facies of the Stuart Bay Formation (Lower Devonian), Bathurst Island, Arctic Canada. Journal of Paleontology, 64:493-510 .

STEARN, C. W. 1991. A revision of *Anostylostroma*, *Atelodictyon*, and related genera (Paleozoic Stromatoporoidea). Journal of Paleontology 65:611-622.

STEARN, C. W. 1993. Revision of the Order Stromatoporida. Palaeontology, 36:201-229.

STEARN, C. W. 1995. The type species of *Stictostroma* Parks, 1936 (Porifera, Stromatoporoidea). Journal of Paleontology, 69:20-27.

STEARN, C.W. 1996. Stromatoporoids from the Devonian (Eifelian to lowest Frasnian) of Manitoba, Canada. Journal of Paleontology, 70:196-217.

STEARN, C. W. 2001. Biostratigraphy of Devonian stromatoporoids faunas of arctic and western Canada. Journal of Paleontology, 75:9-23.

STEARN, C. W., AND P. N. MEHROTRA. 1970. Lower and Middle Devonian stromatoporoids from northwestern Canada. Geological Survey of Canada Papers, 70-13, 43 p.

STEARN, C. W., AND D. H. SHAH. 1990. Devonian (Givetian-Frasnian) stromatoporoids from the subsurface of Saskatchewan, Canada. Canadian Journal of Earth Sciences, 27:1746-1756.

STEARN, C. W., B. D. WEBBY, H. NESTOR, AND C. W. STOCK. 1999. Revised classification and terminology of Palaeozoic stromatoporoids. Acta Palaeontologica Polonica 44:1-70.

STOCK, C. W. 1973. Upper Devonian stromatoporoids of north-central Iowa. Unpublished M.A. Thesis, State University of New York at Binghamton, Binghamton, New York, 127 p.

STOCK, C. W. 1982. Upper Devonian (Frasnian) Stromatoporoidea of north-central Iowa: Mason City Member of the Shell Rock Formation. Journal of Paleontology, 56:654-679.

STOCK, C. W. 1984. Upper Devonian (Frasnian) Stromatoporoidea of north-central Iowa: rediscription of the type specimens of Hall and Whitfield (1873). Journal of Paleontology, 58:773-788.

STOCK, C. W. 1990. Biogeography of Devonian stromatoporoids. Geological Society, London, Memoir 12, p. 257-265.

STOCK, C. W. 1991. Lower Devonian (Lochkovian) Stromatoporoidea from the Manlius Formation of New York. Journal of Paleontology, 65:897-911.

STOCK, C. W. 1997. Lower Devonian (Lochkovian) Stromatoporoidea from the Coeymans Formation of central New York. Journal of Paleontology, 71:539-553.

STOCK, C. W. 2005. Devonian stromatoporoid originations, extinctions, and paleobiogeography: how they relate to the Frasnian-Famennian extinction, p. 71-92. *In* D. J. Over, J. R. Morrow, and P. B. Wingnall (eds.), Understanding Late Devonian and Permian-Triassic Biotic and Climatic Events: Towards an Integrated Approach. Elsevier, Amsterdam.

WAAGEN, W., AND J. WENTZEL. 1887. Class Hydrozoa, p. 925-962. *In* W. Waagen (ed.), Salt Range Fossils VI, Productus limestone fossils. Palaeontologia India, Geological Survey of India, Memoires, Series 13.

WARME, J. E. 2004. The many faces of the Alamo Impact Breccia. Geotimes, 49(1):26-29.

WARME, J. E., AND H. C. KUEHNER. 1998. Anatomy of an anomaly: the Devonian catastrophic Alamo Impact Breccia of southern Nevada. International Geology Review, 40:189-216.

WARME, J. E., AND C. A. SANDBERG. 1995. The catastrophic Alamo Breccia of southern Nevada: record of a Late Devonian extraterrestrial impact. Courier Forschungsinstitut Senckenberg, 188:31-57.

WARME, J. E., J. R. MORROW, AND C. A. SANDBERG. 2008. Devonian carbonate platform of eastern Nevada: facies, surfaces, cycles, sequences, reefs, and cataclysmic Alamo Impact Breccia. The Geological Society of America Field Trip Guide, 11:215-239.

WEBBY, B. D., STEARN, C. W., AND Y. Y. ZHEN. 1993. Lower Devonian (Pragian-Emsian) stromatoporoids from Victoria.— Proceeding of the Royal Soceity of Victoria 105(2):113-186.

WEBBY, B. D., AND Y. Y. ZHEN. 1993. Lower Devonian stromatoporoids from the Jesse Limestone of the Limekilns area, New South Wales. Alcheringa, 17:327-352.

YANG, J. Z., AND D. Y. DONG. 1979. Devonian stromatoporoids from central and eastern parts of Guangxi, China [in Chinese with English summary]. Paleontologia Sinica, 157, New Series B, 1-89.

YAVORSKY, V. I. 1931. Nekotorye devonskie Stromatoporoidea iz okrain Kuznetskogo basseina, Urala i drugikh mest. (Some Devonian stromatoporoids from the outskirts of The Kuznetsk Basin, the Ural and other localities.) Izvestiya Vsesoyuznogo Geologo-Razvedochnyi obedineniya, 50:1387-1415.

YAVORSKY, V. I. 1965. Nekotorye siluriiskie i devonskie stromatoporoidei Pechorskogo Basseina, 218-246 p., *In* M. V. Kulikov (ed.), Biostratigrafischeskii sbornik 1. Gosudar-stvennyi Geologicheskii Komitet SSSR, Vsesoyuznogo Nauchno-Issledovatel’skogo, Geologicheskogo Instituta (VSEGEI), Trudy, Novaya Seriya.

YAVORSKY, V. I. 1967. Stromatoporoidea Sovetskogo Soyuz, Part 5. Ministerstvo Geologii SSSR, Vsesoyuznogo Nauchno-Issledovatel’skogo Geologicheskogo Instituta (VSEGEI), Trudy, Novaya Seriya, 148, 120 p.

YAVORSKY, V. I. 1969. Novye rod *Intexodictyonella* iz svendneg Devona Kuznetskogo bassenia. Paleontologicheskii Zhurnal, 1969(4):102-104. [Translated in Paleontological Journal, 3:542-544.]

YAVORSKY, V. I. 1974. Reviziya nekotorykh paleozoiskikh stromatoporoidei Kuznetskogo basseina, Urala I drugikh raionov, 228-245. *In* N. P. Luppov (ed.), Biostratigraficheskii Sbornik 5. Vsesoyuznogo Ordena Lenina Nauchno-Issledovetelskogo, Geologicheskogo Instituta (VSEGEI), Trudy, 182.

ZIEGLER, W., AND C. A. SANDBERG. 1990. The Late Devonian standard conodont zonation. Courier Forschungsinstitut Senekenberg, 121, 115 p.

ZUKALOVA, V. 1971. Stromatoporoidea from the Middle and Upper Devonian of the Moravian Karst. Rozpravy Ustredniho Ustavu Geologickeho, 37, 143 p.