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Inventory of Dominantly Marine and Brackish-Water Fossils from Late Cretaceous Rocks in and near Grand Staircase-Escalante National Monument, Utah

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ABSTRACT

A digital inventory of predominantly marine and brackish-water invertebrate fossils from Late Cretaceous rocks has been compiled for the newly designated Grand Staircase--Escalante National Monument based on U.S. Geological Survey collections obtained during the past three decades. The inventory contains 168 collections and descriptions of invertebrate fossils from more than 100 localities from the upper part of the Dakota Formation, Tropic Shale, Straight Cliffs Formation, and equivalent units which include rocks of late Cenomanian through late Santonian age. Some of the identified fauna were not previously reported from southwestern Utah.

For many fossil localities in the monument, the inventory provides data on the presence of ammonites and bivalves that are used to correlate marine Cretaceous rocks in southwestern Utah with equivalent rocks in other regions. The inventory also contains (1) information on the geologic age, lithologic characteristics, and depositional environments of rock units; (2) a map of fossil localities within the monument indicated; (3) a chronostratigraphic chart showing the positions of collections within the standard Cretaceous ammonite biozones; (5) six measured sections illustrating the range of lithologies from which the fauna were derived; and (6) photographs of selected ammonites and inoceramids and views of the measured sections from which they were collected.

The oldest marine Cretaceous rocks in the Grand Staircase-Escalante National Monument occur in the early late Cenomanian *Dunveganoceras albertense* biozone of the Dakota Formation in the western part of the monument at Cottonwood Wash. Marine sandstones in the Straight Cliffs Formation represent the overall regressive phase of the seaway and contain biozones ranging from late middle Turonian through the Santonian.

The inventory was compiled using EXCEL 97 and includes fossil name and type, U.S. Geological Survey identification number, collection location information, stratigraphic position of collection, biozone, and general remarks. The inventory can be sorted and modified using standard EXCEL queries.

INTRODUCTION

During the period 1963-1999, 168 collections of Cretaceous invertebrate fossils were made from more than 100 localities in the area now included in the Grand Staircase-Escalante National Monument (figure 1). The collections represent the following stages of the Cretaceous Period (65-142 million years ago): Cenomanian (upper part), Turonian (lower and middle parts), Coniacian (middle and upper parts), and Santonian (middle and upper parts). Pre Cenomanian and post Cretaceous rocks are absent from the monument. Most collections were made by members of the U.S. Geological Survey (USGS). The collectors and years of collection are as follows: H.A. Waldrop (1963-1965), H.D. Zeller (1964-1966), B.E. Law (1966), G.H. Horn

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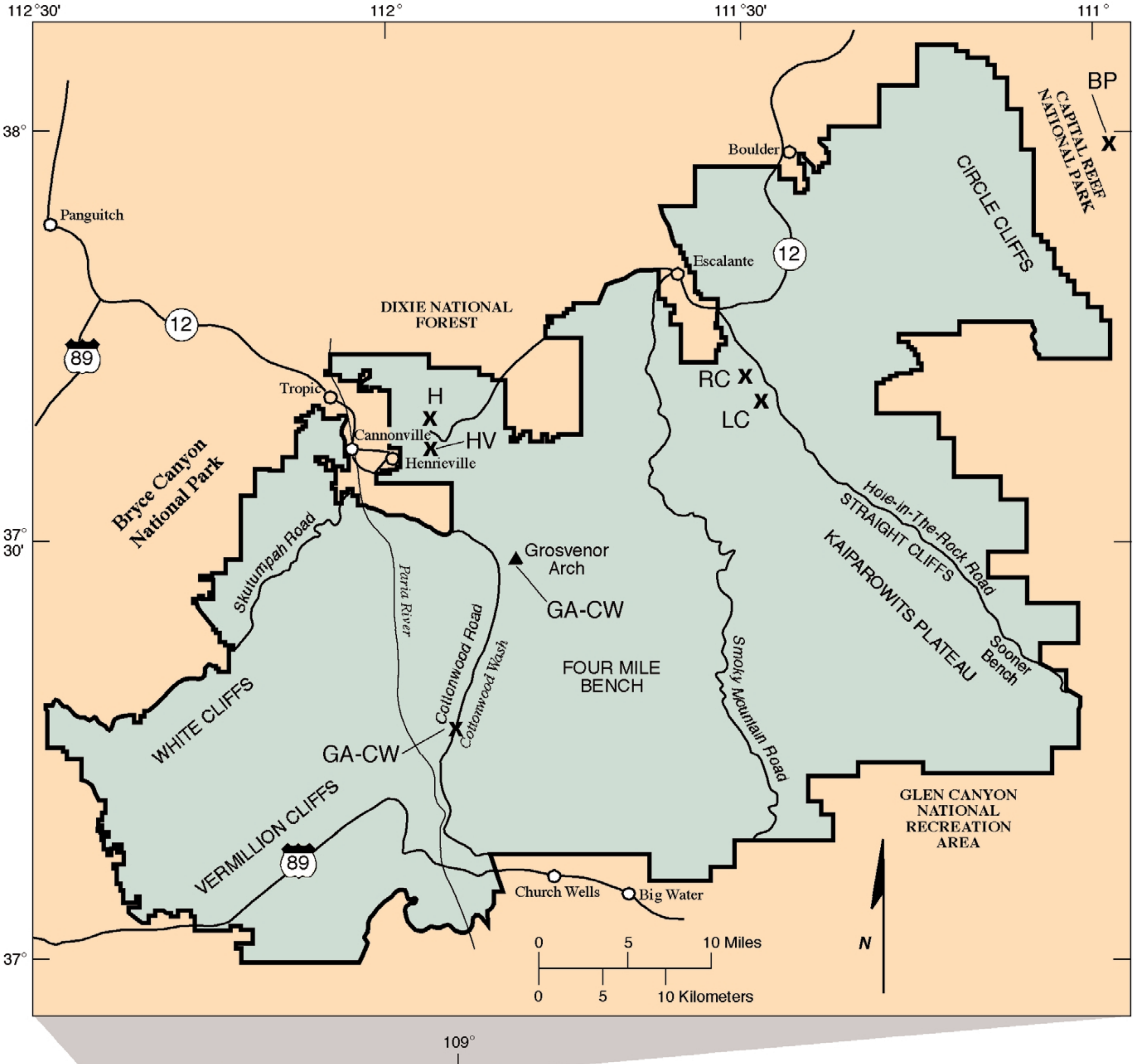


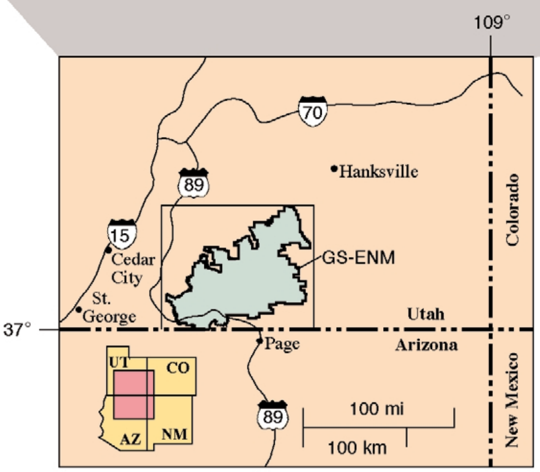


Figure 1. Index map of Grand Staircase-Escalante National Monument illustrating major geographic features, highways, and towns. Measured section localities as follows: GA-CW, Grosvenor Arch-Cottonwood Wash; H, Henrieville; HV, Henrieville Valley; RC, Right-Hand Collet Canyon; LC, Left-Hand Collet Canyon; BP, Bitter Spring Creek-The Post.

(1966), E.V. Stephens (1966, 1967), F. Peterson (1965-1975), W.E. Bowers (1966-1970), F.B. Zelt (1982-1984), G.L. Pollock (1989-1999), T.S. Dyman (1994-1999), C.A. Derewetzky (1997), W.A. Cobban (1966-1999), and I. Walaszczyk (1999). Fossils were identified primarily by W.A. Cobban and G.L. Pollock. The inventory does not include collections of non-USGS personnel, particularly the collections of those researchers published earlier in the last century. In many cases, exact geographic locations of older collections could not be documented by us, and many uncertainties exist due to fossil name changes through the years. For information on other marine Cretaceous collections as well as collections for other rock units in the monument refer to Gillette and Hayden (1997).

The inventory is included on CD-ROM (UGA Publication 29) as an EXCEL data file with supporting files of information. This written report contains: (1) information on the geologic age and lithologic characteristics of the chief rock units from which the fossils were collected; (2) a map of the monument indicating fossil localities; (3) a chronostratigraphic chart showing the positions of collections within the standard Cretaceous ammonite biozones. Other supporting information on CD-ROM includes: (1) graphic displays of six measured sections and accompanying photographs illustrating the range of lithologies from which the fauna were derived; and (2) photographs of selected ammonites and other fossils and views of the measured sections from which many of them were collected.

The purpose of the digital inventory is to present fossil descriptions and supporting information for marine invertebrate collections from the monument as a digital resource for students, teachers, researchers, and the general public. Applications include studies of the energy, mineral, and environmental resources of the monument. Fossil information compiled from the inventory has been incorporated into educational outreach activities in school districts in the form of lectures, field trips, and teacher training programs. Graduate school theses and other academic research projects have incorporated these data. The fossil collections are stored at the USGS in Denver, CO 80225. The authors wish to acknowledge Robert Hettinger and Katherine Varnes, U.S. Geological Survey, Denver, CO for their critical reviews of the manuscript.

CRETACEOUS EPEIRIC SEA

Marine Cretaceous rocks of the monument were deposited along the western margin of a large sea within the continent of North America known as the Cretaceous epeiric sea (figure 2). Sediments were deposited by this sea in a large basin called the Western Interior basin, which is one of the largest and most economically viable sedimentary basins in the world. Energy and mineral resources including coal, uranium, petroleum, natural gas, bentonite, and building stone have been produced in the Western Interior basin for many years. The prairies, mountains, and valleys that today occupy this geographic region offer some of the most scenic and environmentally valuable lands of the American west. Figure 2B illustrates the asymmetric basin profile in which sedimentary rocks range in thickness from more than 20,000 feet in the west in the thrust belt of western Montana, Wyoming, and Utah to less than 1,000 feet in eastern North and South Dakota, and in Nebraska and Kansas. The tectonically active western margin was dominated by coarse clastic sediments deposited in generally nonmarine environments, while the tectonically quiet eastern margin and central shelf were dominated by marine shales and carbonates. The two cross sections of figure 2 illustrate the change in basin configuration through time. During the Early Cretaceous, the basin resembled a wedge thinning to the east (figure 2B), whereas during the Late Cretaceous, this wedge was broken into a series of smaller "Laramide" tectonic basins formed by continental-scale plate-tectonic events along the western margin of North America and by local uplifts and igneous intrusions (figure 2C).

MEASURED SECTIONS

Six measured sections are included on the CD-ROM (UGA Publication29) in graphic form. They represent much of the range in lithologic variation within and near the monument. They are located near: Grosvenor Arch-Cottonwood Wash, Henrieville, Henrieville Valley, Left Hand Collet Canyon, Right Hand Collet Canyon, and The Post-Bitter Creek, and each measured section is named for its locality (figure 1). Each graphical measured section includes the dominant lithologies, significant fossils, comments regarding characteristics of the strata, references to key collection numbers from the digital inventory, and reference numbers which can be used to identify photographs representing parts or all of each measured section. Lithologies have been simplified to accommodate the scale of presentation.

FOSSIL PHOTOGRAPHS

Photographs of 26 of the more than 200 species identified at Grand Staircase-Escalante National Monument are also included in the digital inventory on the CD-ROM (UGA Publication 29). These fossils are either among the most abundant in the monument or represent rarer but important guide fossils. Photographs were taken of line drawings and original photographs from published reports dealing with each species. Photograph captions identify the chief characteristics of each species and list the published source from which the photograph or drawing was taken.

Species include the following:

Inoceramus pictus Sowerby
Mytiloides mytiloides (Mantell)
Euomphaloceras septemseriatum (Cragin)
Sciponoceras gracile (Shumard)
Neocardioceras juddii (Barrois and de Guerne)
Baculites codyensis Reeside
Pycnodonte newberryi (Stanton)
Exogyra (Costagyra) olisiponensis Sharpe
Inoceramus mesabiensis Bergquist
Metoicoceras geslinianum (d'Orbigny)
Collignoniceras woollgari regulare (Haas)
Prionocyclus hyatti (Stanton)
Flemingostrea prudentia (White)
Inoceramus howelli White
Clioscaphites vermiformis (Meek and Hayden)
Volviceramus involutus (Sowerby)
Inoceramus (Magadiceramus?) stantoni Sokolow
Protexanites bourgeoisianus (d'Orbigny)
Gyrodes depressa Meek
Perissoptera prolabiata (White)
Cymbophora utahensis Meek

STRATIGRAPHY AND AGE

Figure 3 is a generalized correlation chart illustrating the stratigraphic position of Cretaceous rocks in the mon-

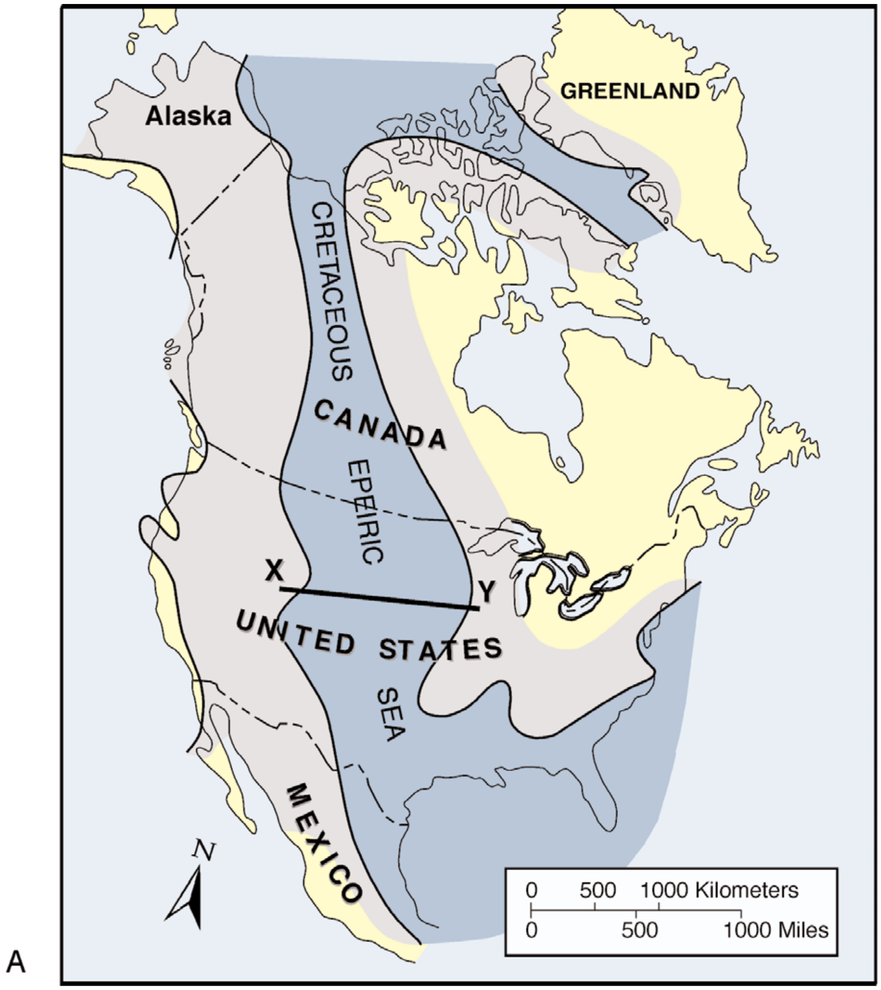
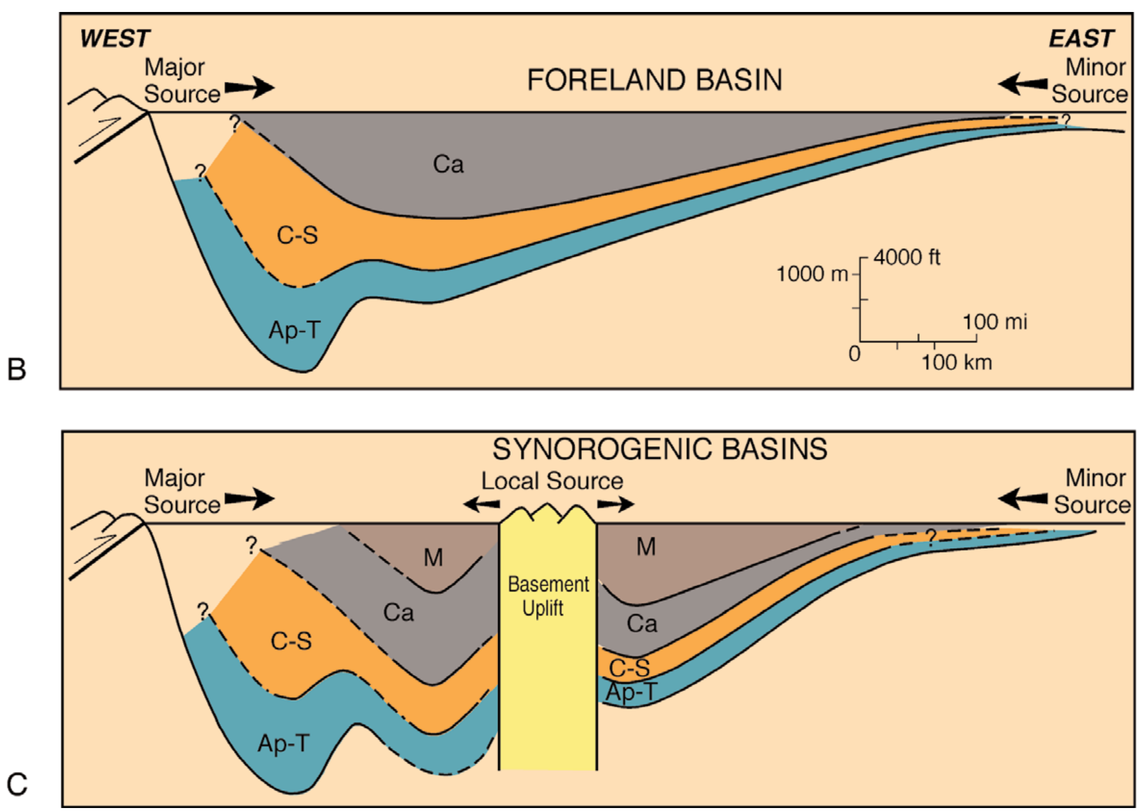


Figure 2. Generalized map and cross sections of Cretaceous eperic sea. (A) Map showing maximum extent of epicontinental seaway during Campanian time (unshaded portion, modified from Gill and Cobban, 1973). Line of cross section X-Y for (B) and (C) shown. Generalized cross sections X-Y shown for late Campanian time (B) and late Maastrichtian time (C). (B) From late Aptian to late Campanian (approximately 115 to 73 million years ago), the Western Interior was a foreland basin bounded on the west by a thrust-faulted tectonically-active area and on the east by a stable craton. Depositionally thick areas occurred along the western margin of the basin and were associated with major western source areas. (C) During the early phase of the Laramide orogeny, crustal blocks were uplifted and the foreland basin was fragmented into smaller synorogenic basins. Abbreviations on cross sections as follows: M, Maastrictian; Ca, Campanian; C-S, Coniacian-Santonian; Ap-T, Aptian-Turonian. Cross sections B and C taken from Dyman and others (1995).



ument, immediately east of the monument in Capitol Reef National Park, and in areas to the west in southwestern Utah. Within the monument, marine rock units include most of the Dakota Formation, Tropic Shale, and Straight Cliffs Formation. At Capitol Reef National Park, marine rocks include most of the Dakota Formation and the overlying Mancos Shale. Figure 4 is a biostratigraphic chart showing Upper Cretaceous stages, formations and members in the Monument, informal stratigraphic units, Western Interior ammonite zones, and localities of biostratigraphically significant fossil collections. These two figures will be helpful in using the digital inventory and reading the following discussion.

The following discussion is divided into two parts: (1) the stratigraphy within and near the monument, and (2) the stratigraphy within and near Capitol Reef National Park.

Grand Staircase-Escalante National Monument

Dakota Formation

In the monument, the oldest marine rocks are found in the upper part of the Dakota Formation (figures 3 and 4). Near the town of Tropic, and southeastward at Grosvenor Arch and Cottonwood Wash (figure 1), the Dakota averages about 300 feet thick and is composed of sandstone, conglomerate, mudstone, siltstone, and coal. The Dakota thins in the eastern part of the monument, where it averages less than 150 feet thick in the Sooner Bench area (figure 1). The base of the formation is identified by a coarse pebble and cobble conglomerate that persists throughout most of the region. Clasts are composed of quartzite, dark-gray chert, and various lithic fragments including sandstone, conglomerate, and mudstone. The basal conglomerate overlies a widespread regional unconformity above Jurassic rocks. Where the conglomerate is absent, the basal Dakota is composed of carbonaceous mudstone, coal, and sandstone. Several distinctive coal zones are present in the middle and upper parts of the Dakota. Sandstones are generally fine to medium grained and lithic rich. At Cottonwood Wash (figure 1), the Dakota was deposited in coastal, floodplain, and shallow marine depositional environments. The Dakota-Tropic Shale contact near the town of Tropic is sharp and marks an abrupt change in lithology from predominantly sandstone to shale.

The oldest marine fossils occur in the uppermost beds of the Dakota which are clearly of late Cenomanian age at the monument (figures 3 and 4). Ammonites are scarce, but the presence of *Metoicoceras mosbyense* and *M. defordi* suggest assignment to some one of the zones of *Vascoceras diartianum*, *Dunveganoceras conditum*, or *D. albertense.* At most localities, the top of the Dakota contains an extensive fauna of bivalves characterized by the oyster *Exogyra (Costagyra) olisiponensis* Sharpe and *Flemingostrea prudentia* (White). At one locality (figure 4; collection 31), *Metoicoceras mosbyense* was found with *E. olisiponensis*, which suggests that the *E. olisiponensis* assemblage lies at the top of the range of *M. mosbyense*. Inasmuch as the highest *M. mosbyense* occurs in the zone of *Vascoceras diartianum*, the highest beds of the Dakota are assigned to this zone. The occasional presence of *M. mosbyense* lower in the upper part of the Dakota suggests assignment to some one of the *Dunveganoceras* zones, such as *D. conditum* or *D. albertense.*

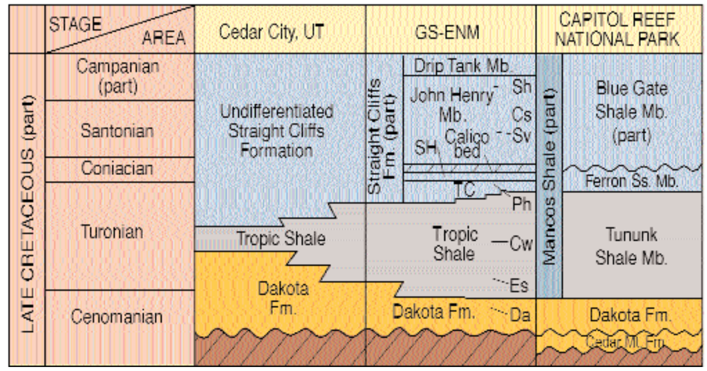


Figure 3. Generalized stratigraphic correlation chart illustrating marine Cretaceous rock units of late Cenomanian through early Campanian in age in the Grand Staircase-Escalante National Monument (GS-ENM), Cedar City area, and equivalent rocks in Capitol Reef National Park. Hatchured areas indicate unconformities. Abbreviations show the stratigraphic location of marine Cretaceous ammonite biozones, associated inoceramids, and stratigraphic units as follows: Cw, Collignoniceras woollgari; Da, Dunveganoceras albertense; Es, Euomphaloceras septemseriatum; Ph, Prionocyclus hyatti; Sv, Scaphites ventricosus; Cs, Clioscaphites vermiformis; Sh, Scaphites hippocrepis; SH, Smoky Hollow Member of Straight Cliffs Formation; TC, Tibbet Canyon Member of Straight Cliffs Formation.

Tropic Shale

The Tropic Shale in the monument averages about 700 to 900 feet thick and is composed of medium to dark-gray fissile shale with occasional thin siltstone and sandstone lenses. The lower part of the formation is generally calcareous and contains several distinctive concretionary zones. The lowermost concretionary zone, which forms a distinct horizon about 15 to 20 feet above the base of the formation, contains the ammonite *Sciponoceras gracile* and associated fauna of the middle late Cenomanian *Euomphaloceras septemseriatum* biozone (figure 4; collections 7, 94, and 95). The *E. septemseriatum* zone is especially fossiliferous and accounts for 21 of the collections in the inventory. A second horizon about 150 feet above the base of the formation contains fauna of the *Vascoceras birchbyi* biozone of early Turonian age (for example, see collection 30). About 700 feet above the base of the formation, at a distinct color change from calcareous to noncalcareous shale, is the approximate first appearance of the ammonite *Prionocyclus hyatti* of late middle Turonian age (figure 4; collections 15 and 60) which is also found in the overlying Tibbet Canyon Member of the Straight Cliffs Formation. A

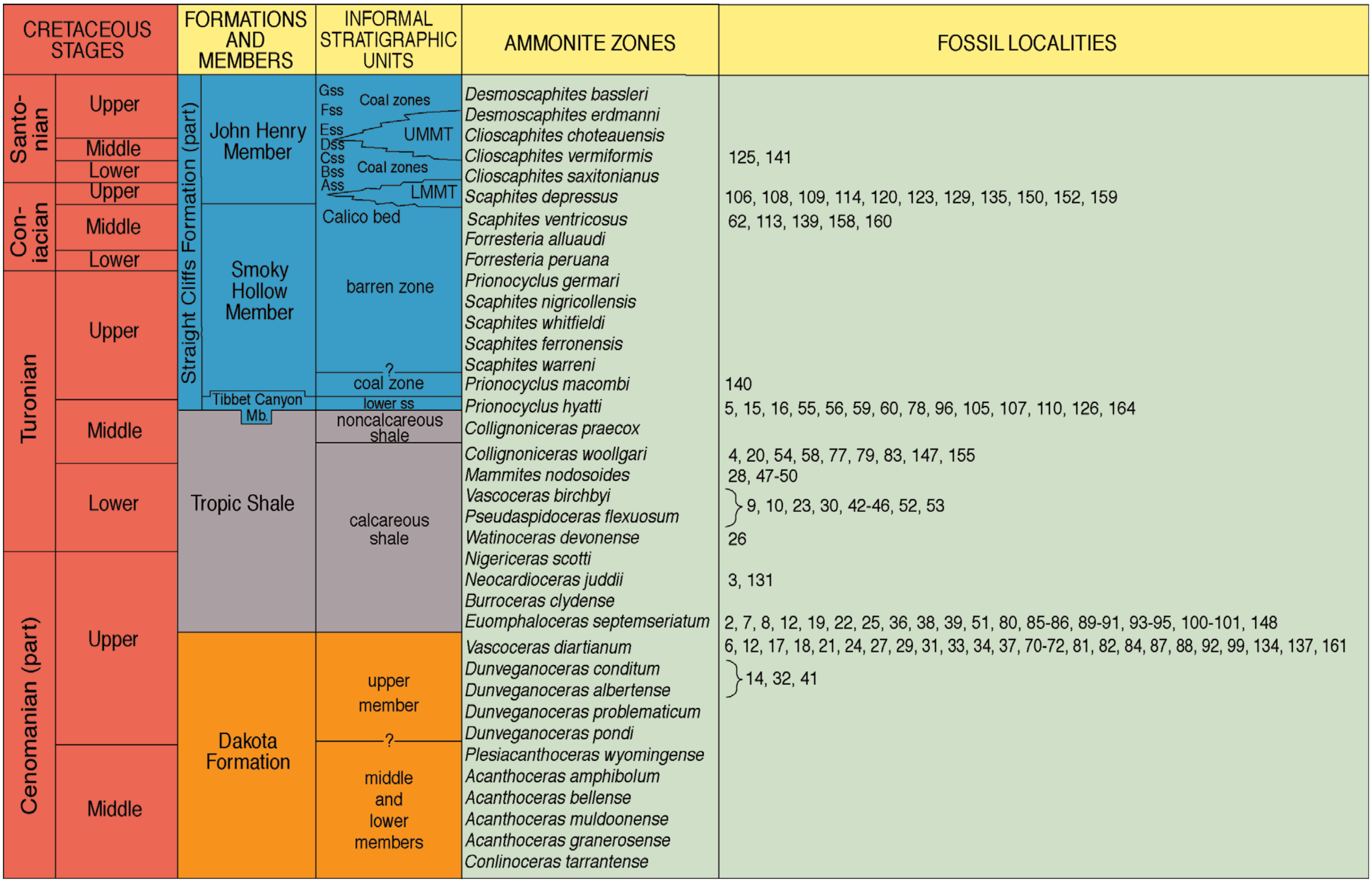


Figure 4. Biostratigraphic chart showing Upper Cretaceous stages, formations and members in the Grand Staircase--Escalante National Monument, informal stratigraphic units, Western Interior ammonite zones (modified from Cobban, in Obradovich, 1993), and localities of fossil collections. Upper part of informal stratigraphic units modified from Peterson (1969). LMMT and UMMT are lower and upper mudstone tongues. Localities of fossil collections are described in text and shown in figure 4. Each number corresponds to the appropriate collection in the inventory. Refer to inventory for generic names of ammonites identified on chart.

similar sharp color change occurs as far east as west-central Kansas where it marks the contact of the underlying Fairport and Blue Hill Members of the Carlile Shale.

The upper part of the Tropic Shale in the monument is gradational with the overlying Tibbet Canyon Member of the Straight Cliffs Formation. Sandstones increase in abundance upward in the upper part of the Tropic until sandstone is the dominant lithology. The Tropic--Straight Cliffs contact is usually placed where sandstones become more abundant than shale (Peterson, 1969).

Bentonite beds (altered ash beds) are abundant throughout the Tropic. Four widely distributed beds of bentonite, lettered A to D, in the Bridge Creek Member of the Greenhorn Limestone at Pueblo, Colorado, by Elder and Kirkland (1985), were traced across the Western Interior basin from Pueblo to Black Mesa in northeastern Arizona by Elder (1985). Bentonite A, lying in the upper Cenomanian biozone of *Euomphaloceras septemseriatum*, has been dated at 93.49 ± 0.89 million years (Ma) ago by Obradovich (1993). Bentonite B, which lies higher in the upper Cenomanian biozone of *Neocardioceras juddii*, was dated by Obradovich at 93.59 ± 0.58 Ma. Bentonite C, which may lie in the lower Turonian biozone of *Pseudaspidoceras flexuosum*, was dated at 93.25 ± 0.55 Ma by Obradovich. Bentonite D, in the lower Turonian biozone of *Vascoceras birchbyi*, was dated at 93.40 ± 0.63 Ma by Obradovich. These beds of bentonite have recently been treated by Elder (1991) from Black Mesa to Wahweep Wash in the northern part of the monument. Refer to Obradovich's paper for a detailed list of all dated bentonites within the middle Cretaceous of the Western Interior basin. Refer also to Zelt (1985) for an alternative zonation for these bentonites and for bentonites higher in the stratigraphic section.

Straight Cliffs Formation

The Straight Cliffs Formation represents the final regressive phase of the Tropic sea. Lithologic descriptions by Hettinger (1995) of core show the clastic-rich formation is lithologically diverse. It contains four named members designated by Peterson (1969). They include: the Tibbet Canyon, Smoky Hollow, John Henry, and Drip Tank Members (figures 3 and 4). Only the Tibbet Canyon and John Henry Members are known to contain marine invertebrate fauna.

Tibbet Canyon Member: The Tibbet Canyon, the lowest member of the Straight Cliffs Formation, is composed of gray-brown, fine- to medium-grained sandstone and interbedded mudstone and shale. Peterson (1969) identified the base of the Tibbet Canyon in the southeastern Kaiparowits Plateau, where sandstone becomes the dominant lithology above the Tropic Shale. The Tibbet Canyon Member is entirely marine and contains the upper middle Turonian guide fossil *Prionocyclus hyatti*. The member ranges in thickness from about 70 to 200 feet in the monument.

Smoky Hollow Member: The Smoky Hollow Member of Straight Cliffs Formation is more lithologically and depositionally heterogeneous than the underlying Tibbet Canyon Member and is composed of interbedded sandstone, mudstone, carbonaceous mudstone, and coal. The base of the member is identified by the presence of a coal and carbonaceous mudstone zone that varies in thickness from 0 to 47 feet (Peterson, 1969). The top of the member is composed of a unit of quartz- and chert-rich sandstone and chert-pebble conglomerate referred to as the Calico bed (Peterson, 1969) (figures 3 and 4) or the Calico sandstone or sequence (Hettinger, 1995). The Calico bed varies in thickness from 0 to about 50 feet and is in sharp contact with the overlying John Henry Member. This sharp contact was interpreted to represent a regional unconformity by Peterson (1969). The unconformity was reinterpreted to be located at the base of the Calico bed by Shanley and McCabe (1991), and the sharp contact at the base of the John Henry was reinterpreted to represent a transgressive surface of erosion by Shanley and others (1992).

A late Turonian age is likely for most of the member (Peterson, 1969). Hettinger (1995, p. A 6) noted the occurrence of an inoceramid bivalve identified as *Cremnoceramus deformis* (Meek) (Hettinger, 1995) 12 feet below the top of the Smoky Hollow Member at a locality southwest of Escalante and barely outside the monument. The inoceramid is probably *Volviceramus involutus* (Sowerby). Middle Coniacian inoceramids have been found at two localities in the monument (figure 4; collections 62, 113). Both are presumably from the John Henry Member.

John Henry Member: The John Henry Member varies in thickness from about 600 feet to more than 1,000 feet in the monument and is composed of interbedded sandstone, mudstone, carbonaceous mudstone, and coal. The upper contact of the John Henry Member is placed at the base of the lowest cliff-forming sandstone of the overlying Drip Tank Member. The John Henry-Drip Tank contact was interpreted to be conformable by Peterson (1969) and it was interpreted to be unconformable by Shanley and McCabe (1991).

In the southwestern third of the monument, the John Henry Member seems to be entirely nonmarine but in the central part of the monument, thick marine sandstones intertongue with coal-bearing units, and farther east, two marine mudstone units intertongue with the sandstones. Peterson (1969) referred to the mudstone units as a "lower marine mudstone tongue" and an "upper marine mudstone tongue" (figure 4). The lower tongue usually has pebbles at the base and rests on an unconformable surface developed on the Calico bed of the Smoky Hollow Member. Ammonites and inoceramids date the lower tongue as late Coniacian. The upper tongue is not well dated, but it has yielded a single fragment of an ammonite assigned to *Clioscaphites vermiformis* (Meek and Hayden) of middle Santonian age. Four major sandstone units separate the two mudstone tongues designated by Peterson (1969): A (lowest) to G (highest). The ammonite *Baculites codyensis* Reeside was collected by Peterson at the boundary of the B and C sandstones (collection 102). It is a late Coniacian to middle Santonian species. The bivalve *Endocostea baltica* (Boehm) was collected by Peterson from the upper part of the upper mudstone tongue (collections 116, 125) as well as from the overlying G sandstone (collection 117). This inoceramid has a range of late Santonian to early Campanian. Peterson also collected the late Santonian--early Campanian inoceramid *Sphenoceramus patootensiformis* (Seitz) from near the top of the G sandstone (figure 4; collection 132). Another significant find by Peterson is a good collection of the inoceramids *Endocostea flexuosa* (Haenlein) and *E. flexibaltica* (Seitz) 350 feet below the top of the Straight Cliffs Formation just outside the monument and about 10 miles northwest of Escalante. According to Seitz (1967) *E. flexuosa* came from rocks assigned to the lower Campanian in Germany, and *E. flexibaltica* has a range of late Santonian--early Campanian in Germany. Troeger (1989, figure 5) shows *E. flexibaltica* as having a very narrow range straddling the late Santonian to early Campanian boundary. Until diagnostic ammonites are discovered in the uppermost part of the Straight Cliffs, that part of the formation is herein regarded as of latest Santonian age, as also suggested by Eaton (1991, p. 52).

Drip Tank Member: The Drip Tank is the uppermost member of the Straight Cliffs Formation and ranges from about 140 feet in thickness in the southern part of the monument to more than 500 feet in the northern part. It is composed of cliff-forming, fine- to medium-grained gray-brown sandstone with well-developed cross stratification. It is entirely nonmarine.

Capitol Reef National Park

Middle Cretaceous rocks at Capitol Reef National Park immediately to the east of the monument include the Dakota Formation and overlying Mancos Shale. The Mancos Shale is subdivided into five members in ascending order: Tununk Shale, Ferron Sandstone, Blue Gate Shale, Emery Sandstone, and Masuk Members. Only the Tununk Shale, Ferron Sandstone, and Blue Gate Shale Members are equivalent to rocks at the monument and are discussed in this section.

Dakota Formation

In Capitol Reef National Park, the oldest marine Cretaceous rocks are located in the upper part of the Dakota Formation (figures 3 and 4). Near The Post and along Bitter Spring Creek in the southern part of the Park (figure 1), the Dakota averages less than 150 feet thick and is composed of sandstone, conglomerate, mudstone, siltstone, and coal. The lower part of the Dakota is entirely nonmarine and contains thin coal seams and carbonaceous mudstone. The base of the formation is identified by a coarse pebble and cobble conglomerate that persists throughout most of the region. Clasts are composed of quartzite, dark-gray chert, and various lithic fragments including sandstone, silicified limestone, and mudstone. The basal conglomerate unconformably overlies the older Cretaceous Cedar Mountain Formation (Peterson and others (1980). The Dakota-Mancos Shale contact near The Post and along Bitter Spring Creek is sharp and marks an abrupt change in lithology from predominantly sandstone in the upper Dakota to shale in the Tununk Member of the Mancos Shale.

The oldest marine fossils occur in the uppermost beds of the Dakota at Capitol Reef National Park (figures 3 and 4). Ammonites were absent from the upper Dakota, but the presence of the oysters *Exogyra (Costagyra) olisiponensis* Sharpe and *Flemingostrea prudentia* (White) supports a late Cenomanian age.

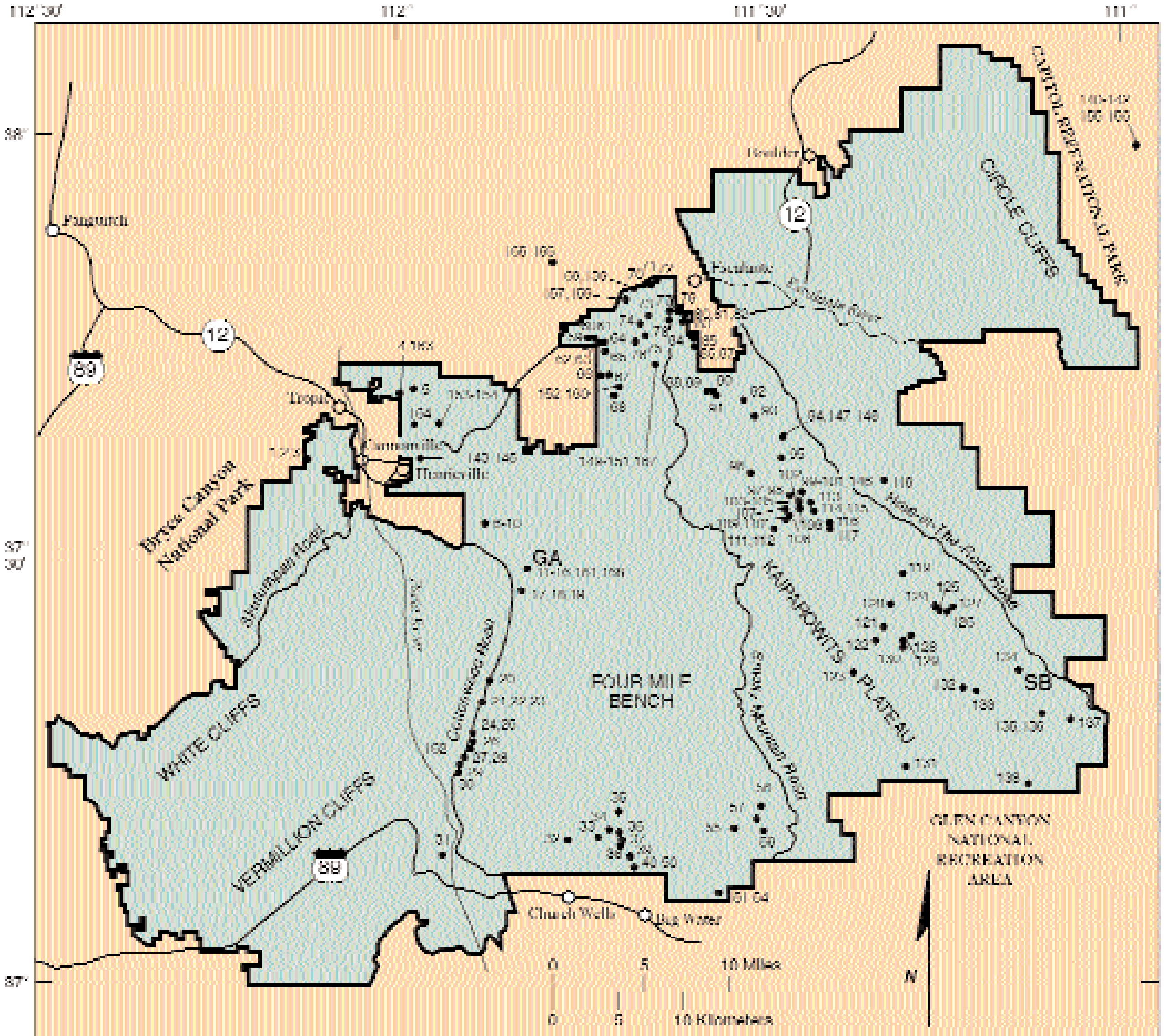
Mancos Shale

Tununk Shale Member: The Tununk Shale Member is the lowest member of the Mancos Shale at Capitol Reef National Park and is composed of medium- to dark-gray bentonitic shale and minor siltstone, mudstone, bentonite, and fine-grained sandstone. It averages about 600 feet thick in the Henry Mountains region east of Capitol Reef National Park and forms low, broad valleys and lowland areas; it is generally poorly preserved (Peterson and others, 1980). The Tununk is about 550 feet thick at the Bitter Spring Creek-The Post measured section.

The contact of the Tununk with the underlying Dakota Formation is poorly exposed but appears sharp in the area of the Bitter Spring Creek-The Post measured section, although Peterson and others (1980) defined the contact as gradational in the Henry Mountains area.

The early middle Turonian guide fossil *Collignoniceras woollgari* has been identified from the middle part of the Tununk Member (figure 3; see collection 155) indicating that the Tununk is corrrelative with the middle part of the Tropic Shale to the west at the monument. *P. hyatti* has been found throughout the region in the Tununk Shale (Peterson and others, 1980; Gardner, 1995).

Ferron Sandstone Member: The Ferron Sandstone Member of the Mancos Shale forms resistant ridges of sandstone between broad lowland areas comprised of less resistant shales in the underlying Tununk and overlying Blue Gate Members. The Ferron also contains abundant mudstone, shale, and coal, and is subdivided into a predominantly marine lower unit and a predominantly nonmarine upper unit (Peterson and others, 1980). The lower unit forms a coarsening-upward sequence capped by a medium- to coarse-grained cross-bedded sandstone. The base of the lower unit is difficult to define because of the interfingering nature of sandstone and shale in the lower part of the lower unit. The unit averages about 150 feet thick in the southern part of Capitol Reef National Park (Peteson and others, 1980), although we measured it to be about 100 feet thick. Some of the difference in thickness may be due to difficulties in interpreting the lower bound-



ary of the lower unit. The upper unit is more heterogeneous lithologically than the lower unit and contains interbedded mudstone, shale, sandstone, and coal. Sandstones form discontinuous channels and are locally conglomeratic. The upper contact of the upper unit and the overlying Blue Gate Shale is sharp and represents a transgressive surface of erosion associated with a sea level rise. The upper unit is about 100 feet thick at the Post-Bitter Spring Creek measured section.

The only marine invertebrate fossil identified by us from the Ferron at The Post-Bitter Spring Creek measured section, *Nicaisolopha bellaplicata*, is a clam which was recognized previously from the middle Turonian zone of *Prionocyclus hyatti* and upper Turonian zone of *Prionocyclus macombi* in New Mexico (see collection 140). Peterson and others (1980) collected *Inoceramus howelli* White from the lower part of the lower unit of the Ferron in the area. The lower part of the Ferron is equivalent to the Tibbet Canyon Member of the Straight Cliffs Formation at the monument (figure 3).

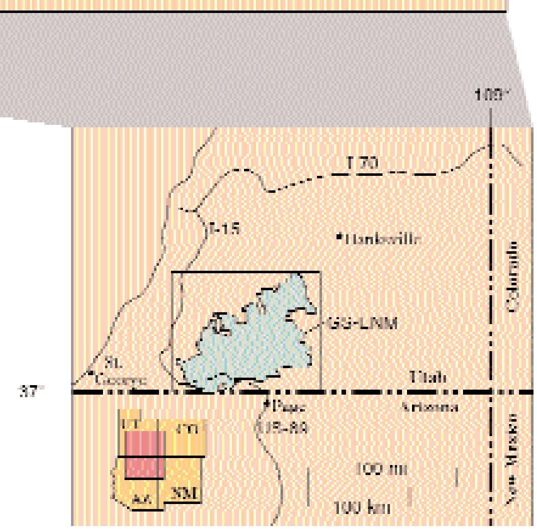


Figure 5. Map of Grand Staircase-Escalante National Monument illustrating major geographic features and the locations of invertebrate marine and brackish-water fossil collections presented in the inventory. Numbers correspond to numbered collections in the inventory. GA, Grosvenor Arch; SB, Sooner Bench.

Blue Gate Shale Member: The Blue Gate Shale Member of the Mancos Shale consists of medium- to dark-gray bentonitic shale and minor bentonite and siltstone. The Blue Gate is very similar to the Tununk Shale Member but is much thicker (Peterson and others, 1980). For this study we measured only the lower part (about 450 feet). The member averages about 1,300 feet thick in the region.

The only fossil assemblage identified (but only noted) from the Blue Gate at the Bitter Spring Creek measured section contains the middle Santonian ammonite *Clioscaphites vermiformis* (Meek and Hayden) (see collection 141).

FOSSIL INVENTORY

Refer also to figures 4 and 5 when using the inventory. Figure 4 illustrates the biozones represented in the monument; collections are identified by number on the chart from this inventory that can be traced to a specific biozone. Figure 4 includes only the ages that span the time included in the marine Cretaceous of the monument. Some collection numbers are not identified on figure 4 because the fossils contained in them are not biozone diagnostic. These collections are left blank in the inventory under biozone. Furthermore, many of the fossils listed in the inventory are not ammonites or are ammonites that are not identified on figure 4. For example, collection 16 includes fossils that are part of the *Prionocyclus hyatti* biozone even if the fossil representing the name of the zone (*P. hyatti*) is not present. The collected fossils are restricted to the named biozone.

Figure 5 is a location map of the monument that illustrates locations of the 168 collections. Each collection is identified by its township, range, and section location, USGS quadrangle map, and county name. Additional locality comments follow the location in the inventory. Stratigraphic location information may vary in precision because of differences in descriptive information provided by collectors. The collection identifiers listed in the inventory (labeled "ID") are USGS Mesozoic locality numbers where D represents Denver, CO. These collections are stored at the Denver Federal Center.

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