Chapter 18
Ammonite Touch Marks in Upper Cretaceous (Cenomanian-Santonian) Deposits of the Western Interior Seaway

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1 Introduction

Over the course of collecting in the last 50 years in the Upper Cretaceous US Western Interior, one of us (WAC) has assembled a collection of “trace fossils” left by ammonites as they touched the sea floor. These impressions provide clues to the taphonomic history of ammonite shells. They also serve as biostratigraphic markers in the absence of ammonite fossils themselves. In the following pages, we illustrate some of these impressions in association with the species that probably produced them.

Ammonite impressions are part of a larger category known as tool marks. The terminology of tool and scour marks has been thoroughly reviewed by Dzułynski and Sanders (1962). We use the term “touch mark” in a general sense for the impression made by the ammonite. What we actually observe of course, is the cast or negative of the impression on the underside of the overlying bed. Twenhofel (1939: 565) referred to such negatives as “counterparts.”

Originally, ammonite touch marks were interpreted as trace fossils produced by vertebrates, e.g., tetrapod claw scratches, or ripple effects caused by fish swimming just above the bottom (as reviewed by Maeda and Seilacher, 1996). Rothpletz (1909) published one of the first correct interpretations, based on his analysis of ammonite

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touch marks from the Jurassic Solnhofen Limestone of Germany. Seilacher (1963) did an extensive study on the marks from this formation, and in a series of memorable figures, illustrated how these marks were produced by waterlogged ammonite shells (perisphinctids and aspidoceratids), in various states of preservation, as they bounced, rolled, and swayed on the seafloor. Gaillard (1977), in a thorough analysis using quantitative data, documented ammonite touch marks in Jurassic strata of the Champagnole region, France. He interpreted the marks as having been produced by the spines of *Euaspidoceras*, as these shells dragged along the bottom. More recently, Summesberger et al. (1999) illustrated roll marks, attributed to perisphinctids, from the Lipica Formation of Slovenia. Each mark ends in a paintbrush-like structure, which the authors interpreted as the impression of the ammonite hyponome.

To better interpret these touch marks, several workers tried to reproduce them experimentally. Dzułynski and Sanders (1962) rolled ammonites on modeling clay, creating marks very similar to those observed in nature. Barthel et al. (1990), in their study of the Solnhofen Limestone, reproduced the marks in this formation by rolling ammonites on wet mud.

Illustrated specimens are reposited in the American Museum of Natural History (AMNH), New York, New York, and the US National Museum (USNM), Washington, DC.

2 Localities

The ammonite touch marks that we describe occur in Upper Cretaceous (middle Cenomanian-middle Santonian) deposits of the US Western Interior. There are 27 localities ranging from Montana to New Mexico, representing 14 ammonite range zones (Figs. 18.1–3). Most of the ammonite touch marks are newly documented, although some have previously been reported (Dzułynski and Sanders, 1962: pl. 19B; Mudge, 1972: A68; Scott et al., 1986: Fig. 12f, g).

The ammonite impressions occur in the Dakota Sandstone of western Colorado, the Juana Lopez Member of the Mancos Shale of New Mexico, the Tropic Shale of Utah, the Lincoln and Hartland Members of the Greenhorn Limestone of Colorado, the Turner Sandy Member of the Carlile Shale of South Dakota, the Floweree and Ferdig Members of the Marias River Shale of Montana, the Cody Shale of Wyoming, and the Niobrara Formation of New Mexico. Ammonite touch marks have not been observed from any strata above the middle Santonian.

The localities of the ammonite touch marks are shown in Figs. 18.1–3 and listed below:

1. US Geological (USGS) Mesozoic loc. D2611. South Fork of Sun River, southwest of junction with Bear Creek, sec. 34, T22N, R10W, Lewis and Clark County, Montana. Approximately 110 ft (33 m) above base of Ferdig Member of Marias River Shale (Mudge, 1972).

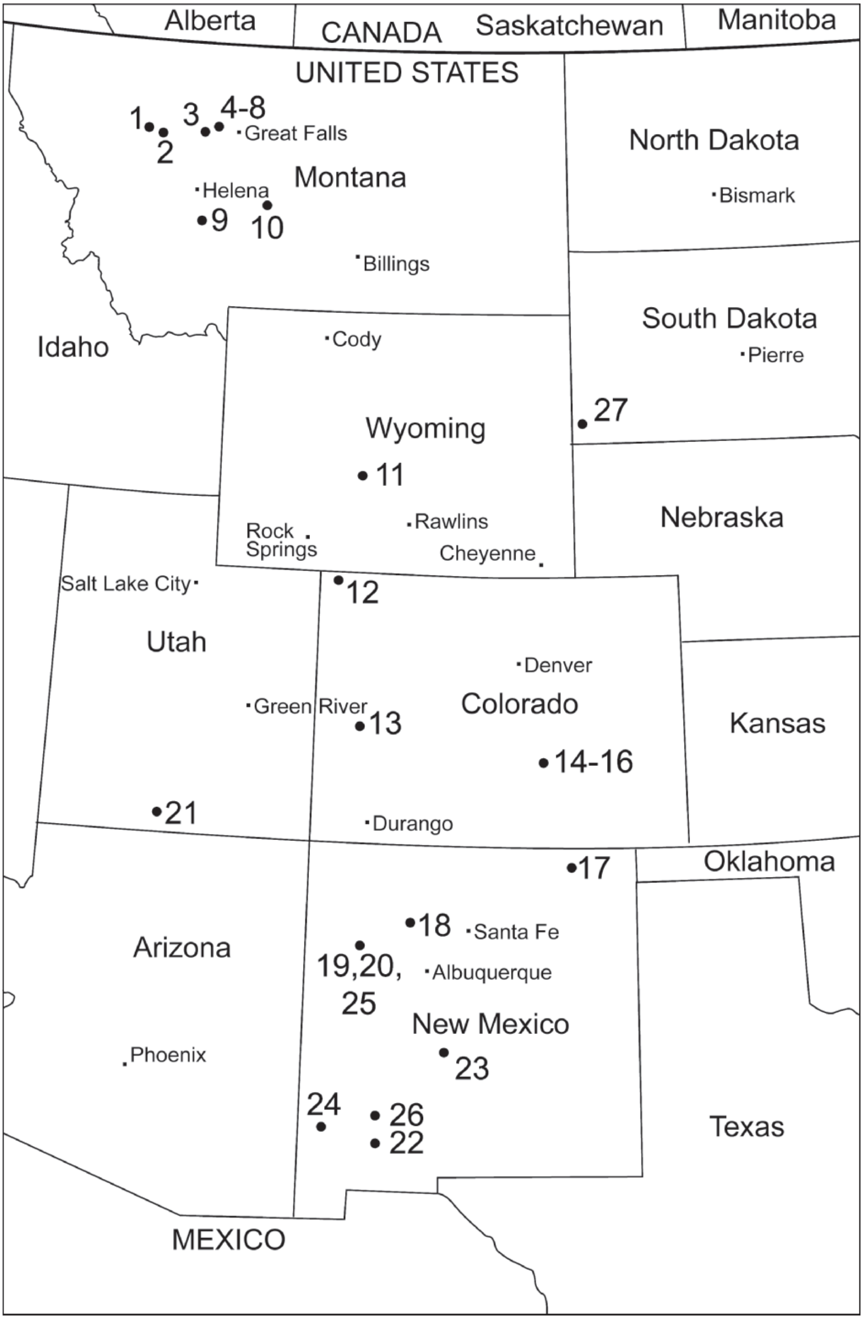

Fig. 18.1 *Map of localities mentioned in the text.*

STAGES AND SUBSTAGES		WESTERN INTERIOR AMMONITE TAXON RANGE ZONES	WESTERN INTERIOR INOCERAMID INTERVAL ZONES	LOCALITIES OF TRACES
Santonian	Upper	*Desmoscaphites bassleri*	*Sphenoceramus lundbreckensis*	
		Desmoscaphites erdmanni		
		Clioscaphites choteauensis	*Cordiceramus muelleri*	
	Middle	*Clioscaphites vermiformis*	*Cordiceramus bueltenensis*	← 11?
			Cordiceramus cordiformis	
	Lower	*Clioscaphites saxitonianus*	*Cladoceramus undulatoplicatus*	
Coniacian	Upper	*Scaphites depressus*	*Magadiceramus crenelatus*	
			Magadiceramus subquadratus	← 17,18
	Middle	*Scaphites ventricosus*	*Volviceramus involutus* *Volviceramus koeneni*	
	Lower	*Scaphites preventricosus*	*Cremnoceramus crassus crassus*	
			Cremnoceramus crassus inconstans	
			Cremnoceramus deformis dobrogensis	
			Cremnoceramus deformis erectus	
Turonian	Upper	*Scaphites mariasensis*	*Cremnoceramus waltersdorfensis*	
		Prionocyclus germari	*Mytiloides scupini*	← 1,2,4-10
		Scaphites nigricollensis	*Mytiloides incertus*	
		Scaphites whitfieldi	*Inoceramus dakotensis*	← 20
			Inoceramus perplexus	
	Middle	*Scaphites ferronensis*	*Inoceramus dimidius*	← 27
		Scaphites warreni		
		Prionocyclus macombi	*Inoceramus* aff. *dimidius*	
		Prionocyclus hyatti	*Inoceramus howelli*	← 12
		Collignoniceras praecox	*Inoceramus* n. sp.	
		Collignoniceras woollgari	*Mytiloides hercynicus*	← 19,21, 25,26
			Mytiloides subhercynicus	
	Lower	*Mammites nodosoides*	*Mytiloides mytiloides*	
		Vascoceras birchbyi	*Mytiloides kossmati*	← 22
		Pseudaspidoceras flexuosum		
		Watinoceras devonense	*Mytiloides puebloensis*	
Cenomanian (Part)	Upper	*Nigericeras scotti*	*Mytiloides hattini*	
		Neocardioceras juddii	*Inoceramus pictus*	
		Burroceras clydense		
		Euomphaloceras septemseriatum		
		Vascoceras diartianum		
		Dunveganoceras conditum	*Inoceramus ginterensis*	← 13,15
		Dunveganoceras albertense		← 3
		Dunveganoceras problematicum		← 14
		Dunveganoceras pondi	*Inoceramus prefragilis*	← 16
	Middle	*Plesiacanthoceras wyomingense*		
		Acanthoceras amphibolum	*Inoceramus rutherfordi*	← 24
		Acanthoceras bellense	*Inoceramus arvanus*	← 23
		Acanthoceras muldoonense	*Inoceramus eulessanus*	
		Acanthoceras granerosense		
		Conlinoceras tarrantense		

Fig. 18.2 *Biostratigraphic distribution of ammonite touch marks. Numbers on the right side correspond to localities plotted in Fig. 18.1 and mentioned in the text. The chart is reproduced from Cobban et al. (2006).*

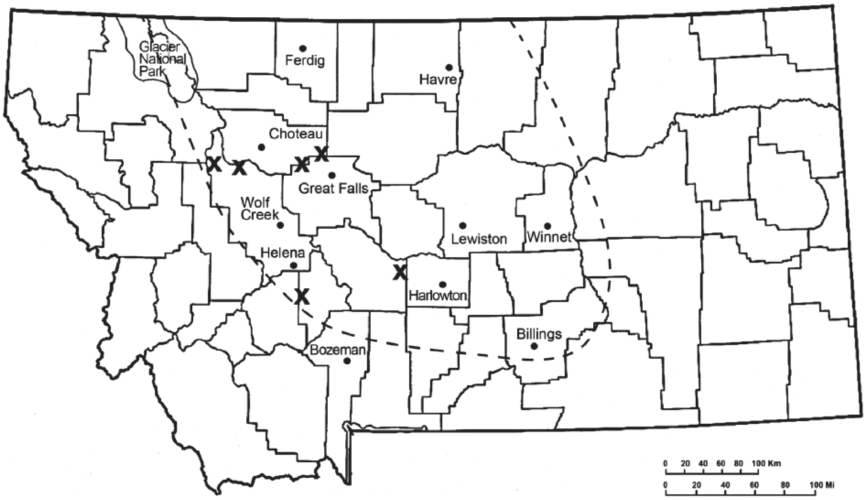

Fig. 18.3 *Map of Montana showing approximate limits of the facies containing scaphitid touch marks in the Ferdig Member of the Marias River Shale. The Xs indicate localities of known touch marks (a single X may represent several closely spaced localities).*

2. USGS Mesozoic loc. D1493. Barr Creek, SW¼ sec. 8, T21N, R8W, Lewis and Clark County, Montana. Ferdig Member of Marias River Shale.
3. USGS Mesozoic loc. D12278. Cone Hill, N½ sec. 13, T22N, R1W, Teton County, Montana. Middle part of Floweree Member of Marias River Shale.
4. USGS Mesozoic loc. D2013. NE¼ sec. 22, T23N, R2E, Teton County, Montana. Bed "N" of Ferdig Member of Marias River Shale (Erdmann et al., 1947; Cobban et al., 1976: 45, 47).
5 USGS Mesozoic loc. D2014. NW¼ sec. 23, T23N, R2E, Teton County, Montana. Bed "N" of Ferdig Member of Marias River Shale (Erdmann et al., 1947; Cobban et al., 1976: 45, 47).
6. USGS Mesozoic loc. D2019. NW¼ sec. 23, T23N, R2E, Teton County, Montana. Approximately 32 ft (9.7 m) above bed "N" of Ferdig Member of Marias River Shale (Erdmann et al., 1947; Cobban et al., 1976: 45, 47).
7. USGS Mesozoic loc. D2254. SW¼ sec. 34, T23N, R1W, Teton County, Montana. Approximately 5.5 ft (1.5 m) above bed "N" of Ferdig Member of Marias River Shale (Erdmann et al., 1947; Cobban et al., 1976: 45, 47).
8. USGS Mesozoic loc. D14366. Northern part of Great Falls 7½ minute quadrangle, T23N, R's 2 and 3E, Teton and Chouteau Counties, Montana. Upper part of Ferdig Member of Marias River Shale.
9. USGS Mesozoic loc. D14085. Indian Creek west of Townsend near middle of sec. 6, T6N, R1E, Broadwater County, Montana. Holter Sandstone Member of Marias River Shale (Groff, 1963).

10. USGS Mesozoic loc. D4593. NW¼ sec. 9, T9N, R11E, Meagher County, Montana. Carlile Shale.
11. USGS Mesozoic loc. D14088. NW¼ sec. 24, T29N, R96W, Fremont County, Wyoming. Cody Shale.
12. USGS Mesozoic loc. D9280. North of Vermillion Creek, NW¼ sec. 30, T10N, R100W, Moffat County, Colorado. Basal 10 ft (3 m) of Frontier Sandstone Member of Mancos Shale.
13. USGS Mesozoic loc. D14083. Highway 50, approximately 7 miles (11 km) west of Delta, Delta County, Colorado. Near top of Dakota Formation.
14. USGS Mesozoic loc. D1307. West of Pueblo, near west line of sec. 30, T20S, R65W, Pueblo County, Colorado. Hartland Shale Member of Greenhorn Limestone.
15. USGS Mesozoic loc. D13241. West of Pueblo, NW¼ sec. 25, T20S, R66W, Pueblo County, Colorado. Hartland Shale Member of Greenhorn Limestone.
16. USGS Mesozoic loc. D13831. Near center of W½ sec. 25, T20S, R66W, Pueblo County, Colorado. Upper part of Lincoln Member of Greenhorn Limestone.
17. USGS Mesozoic loc. D11309. SE¼ sec. 23, T29N, R25E, Colfax County, New Mexico. Sandy Member of Niobrara Formation.
18. USGS Mesozoic loc. D13967. SE¼ sec. 8, T17N, R1W, Sandoval County, New Mexico. El Vado Sandstone Member of Mancos Shale.
19. USGS Mesozoic loc. D10590. Sec. 17, T15N, R12W, McKinley County, New Mexico. Mancos Shale.
20. USGS Mesozoic loc. D13101. SW¼ sec. 17, T15N, R11W, McKinley County, New Mexico. Near top of Juana Lopez Member of Mancos Shale.
21. USGS Mesozoic loc. D13760. NW¼ sec. 14, T40S, R1W, Kane County, Utah. Approximately 175 ft (53 m) below top of Tropic Shale.
22. USGS Mesozoic loc. D11531. Cookes Range, NE¼ sec. 13, T21S, R9W, Luna County, New Mexico. Lower part of sandy unit overlying Bridge Creek Limestone Member of Mancos Shale.
23. USGS Mesozoic loc. D10128. Carthage area, NE¼ sec. 8, T5S, R2E, Socorro County, New Mexico. Thin-bedded siltstone beds beneath Marker bentonite bed of Mancos Shale.
24. USGS Mesozoic loc. D12744. Riley Canyon, NW¼ sec. 21, T18S, R20W, Hidalgo County, New Mexico. Mancos Shale.
25. USGS Mesozoic loc. D5770. NW¼ sec. 28, T15N, R12W, McKinley County, New Mexico. Slightly above Bridge Creek Limestone Member of Mancos Shale.
26. USGS Mesozoic loc. D11022. SW¼ NE¼ sec. 13, T14S, R4W, Sierra County, New Mexico. Shaly siltstone unit 30 feet (9 m) above top of *Sciponoceras gracile* Zone, Mancos Shale.
27. USGS Mesozoic loc. D12874. NE¼ NW¼ sec. 36, T7S, R6E, Fall River County, South Dakota. Float from 5–15 ft (1.5–4.6 m) above the base of the Turner Sandy Member of the Carlile Shale.

3 Description of Ammonite Touch Marks

Careful examination of the ammonite touch marks reveals the species that probably produced them (Figs. 18.4–21, arranged in taxonomic order). The main evidence for this determination is the impression of the ornamental features (ribs, tubercles, and keels), which form a distinctive pattern. We compared this pattern to specimens in our collections, bearing in mind that the pattern of ornamentation commonly changes during ontogeny. We examined those ammonites known to occur in the same strata as the impressions and in age-equivalent strata from elsewhere.

Most of the touch marks were produced by acanthoceratid ammonites including species of *Collignoniceras*, *Calycoceras*, and *Tarrantoceras*. These ammonites were widespread in the Late Cretaceous Western Interior Seaway. Other touch marks in our collection were produced by scaphitid ammonites.

The majority of touch marks are impressions of the venter or ventrolateral edge of the shell, as inferred from the kind and distribution of ornamental features. For example, the ventral impression of scaphitid ammonites consists of a series of 5–10 straight ridges resembling scratch marks (Fig. 18.5A), while the ventral impression of *Tarrantoceras* consists of three parallel rows of small bumps (Fig. 18.12A). The ventrolateral impression of *Collignoniceras woollgari* (Mantell, 1822) consists of a series of clavate ridges (Fig. 18.17A), while the ventrolateral impression of *Fagesia catinus* (Mantell, 1822) shows a break in the shape of the ridges, corresponding to a change in the shape of the whorl section as it passes from the flanks to the venter (Fig. 18.14).

The ammonite touch marks show a broad range in size. Those attributed to *Dunveganoceras conditum* (Haas, 1951) (Fig. 18.8) and *Calycoceras* aff. *C. canitaurinum* (Haas, 1949) (Fig. 18.10) are the largest, whereas those attributed to *Scaphites corvensis* Cobban, 1952 (Fig. 18.6B) are the smallest. In addition, the impressions vary in how faithfully they reproduce the original morphology. For example, the impression of the shell flanks attributed to *Prionocyclus novimexicanus* (Marcou, 1858) is very faithful (Fig. 18.19), whereas the ventrolateral impression attributed to *Protexanites bourgeoisianus* (d'Orbigny, 1850) is distorted, with twisted ribs (Fig. 18.16A). The impressions also vary in their degree of relief. For example, the touch mark attributed to *Calycoceras* aff. *C. canitaurinum* (Fig. 18.10) is very prominent, whereas that attributed to *Pseudaspidoceras flexuosum* Powell, 1963, is very faint (Fig. 18.13).

The touch marks of scaphitid ammonites are extremely abundant (Figs. 18.4, 18.5, 18.6A–D). For example, there are nine sets of impressions on a single slab 10 cm on each side (Fig. 18.5A). All of the impressions on this slab reflect the venter and show no preferred orientation.

The most spectacular ammonite impressions are roll marks or "tire tracks." Figure 18.11 depicts a "tire track" approximately 10 cm long and 4 cm wide, probably produced by an acanthoceratid ammonite like *Tarrantoceras* rolling on the seafloor. The track consists of five parallel rows of bumps and forms a slightly arcuate pattern. Other roll marks in our collection were produced by *Collignoniceras woollgari*. In Fig. 18.17C, the roll mark is slightly arcuate and represents the

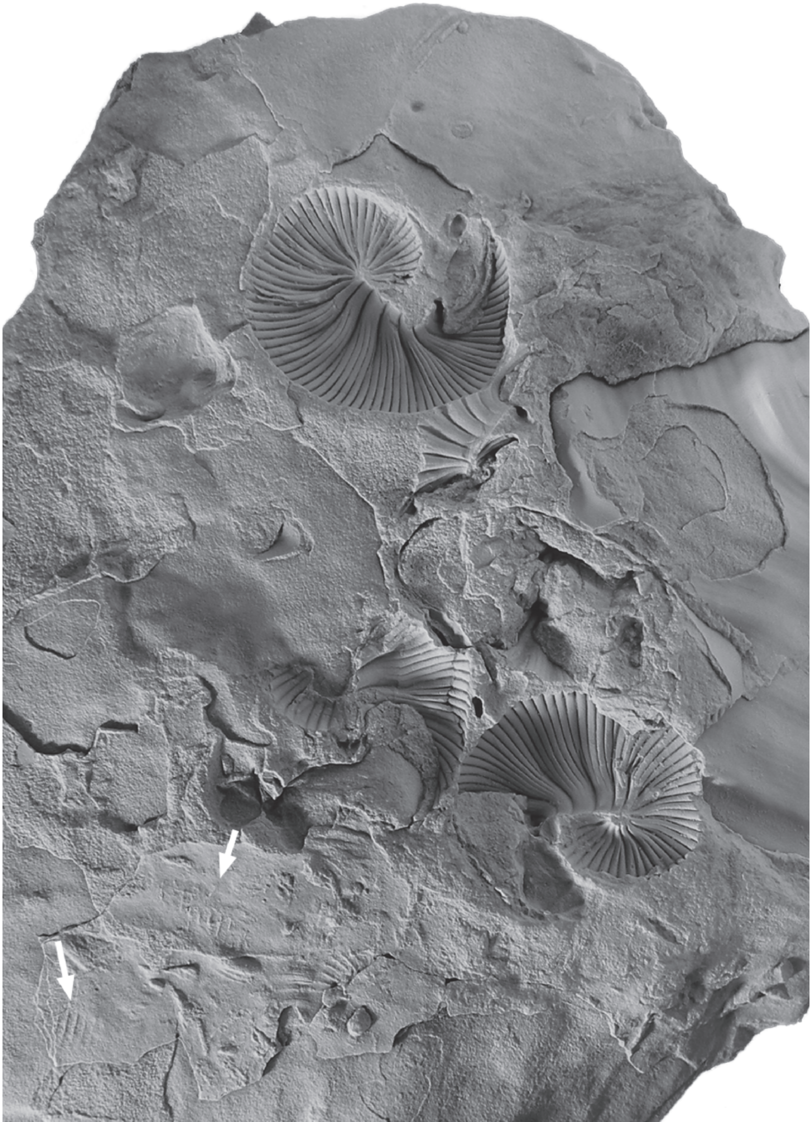

Fig. 18.4 *Scaphitid touch marks, USNM 534416, from the upper part of the Ferdig Member of the Marias River Shale in northcentral Montana (loc. 4, Fig. 18.1). The touch marks (arrows) and steinkerns can be assigned to* Scaphites corvensis *Cobban, 1952. Similar impressions are also present in the Ferdig Member elsewhere in northcentral (locs. 5–8), northwestern (locs. 1, 2), westcentral (loc. 9), and southcentral Montana (loc. 10). X1.*

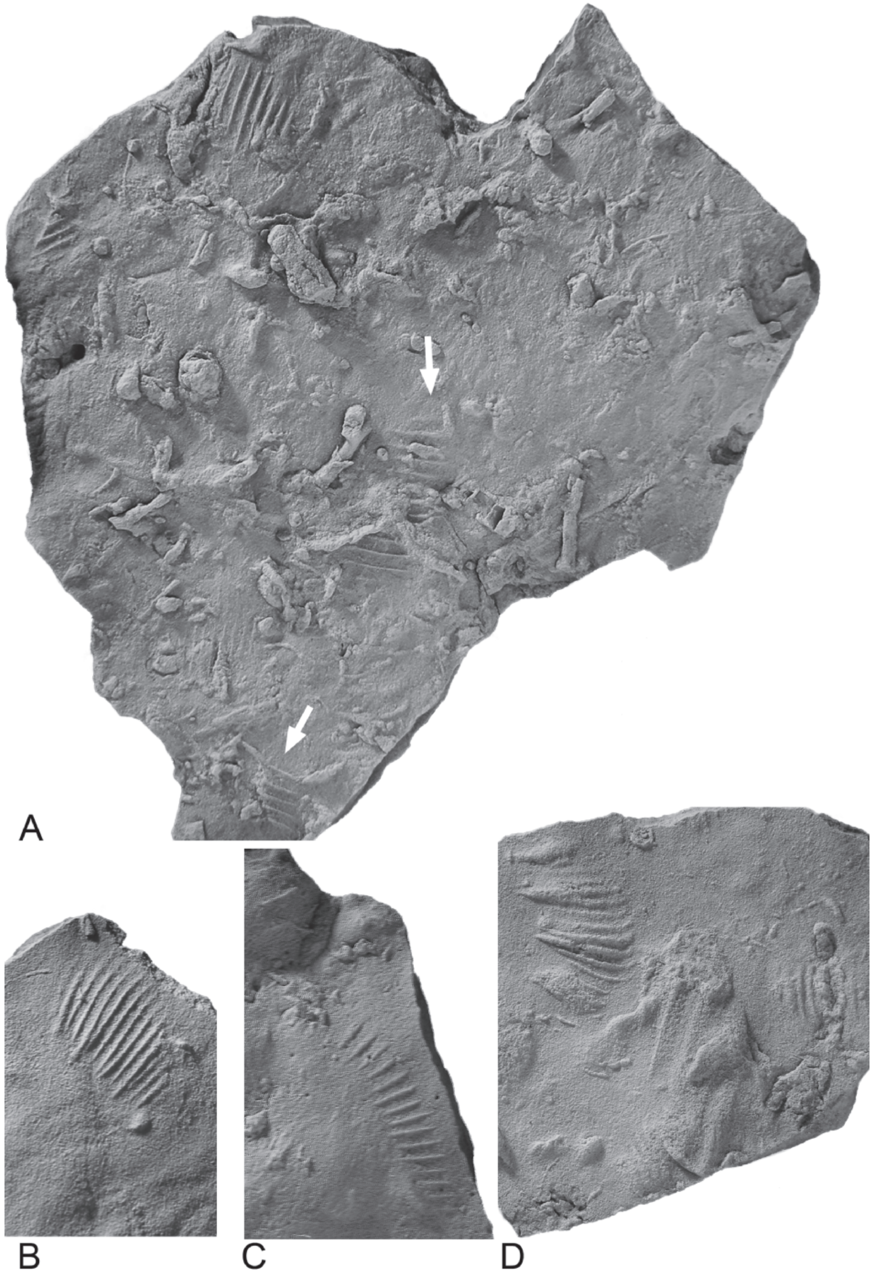

Fig. 18.5 *Scaphitid touch marks (arrows) attributed to* Scaphites corvensis *Cobban, 1952, Ferdig Member of the Marias River Shale in northcentral Montana (loc. 6, Fig. 18.1). A. USNM 534417. B. USNM 534418. C. USNM 534419. D. USNM 534420. All figures X1.*

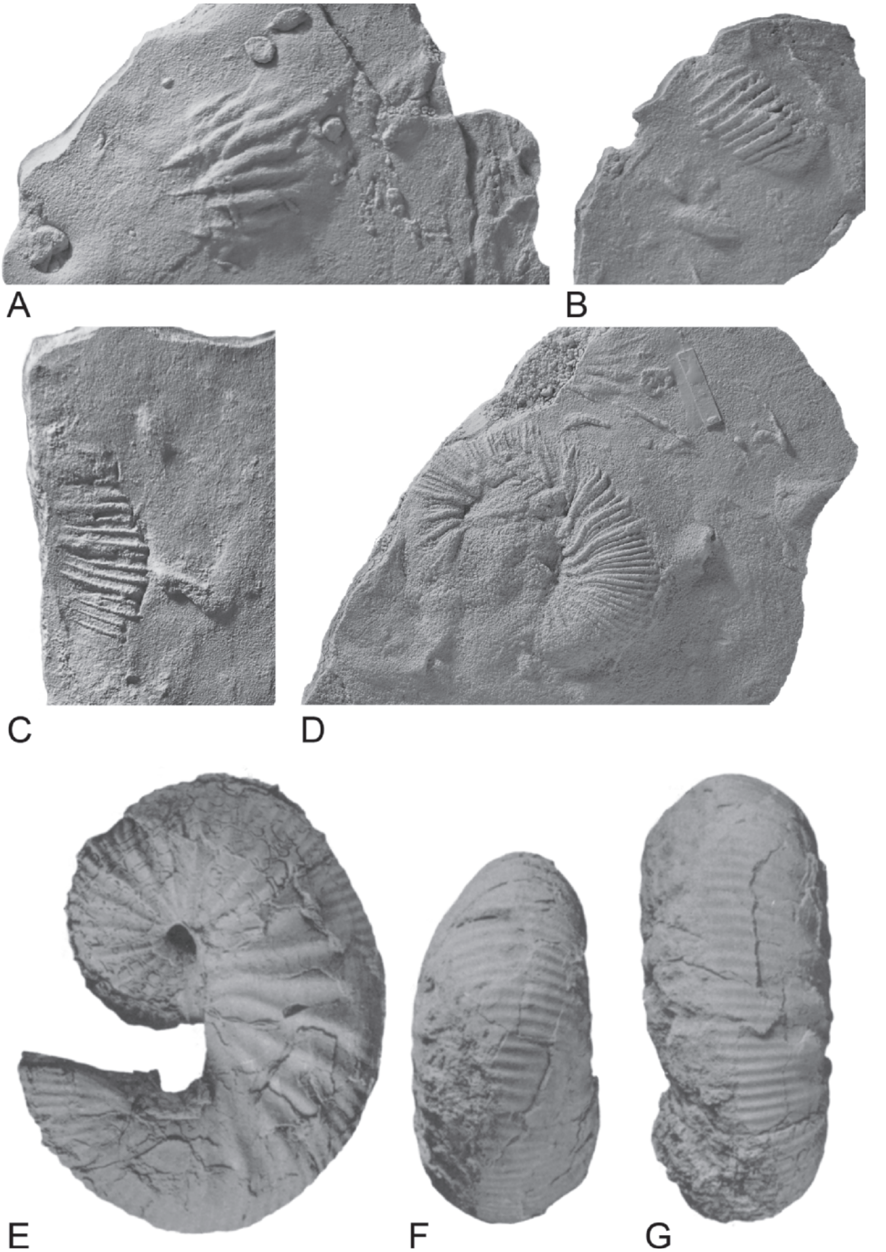

Fig. 18.6 *A–D. Scaphitid touch marks attributed to* Scaphites corvensis *Cobban, 1952, Ferdig Member of the Marias River Shale in northcentral Montana (Fig. 18.1). A. USNM 534421 (loc. 8, Fig. 18.1). B. USNM 534422. C. USNM 534423 (loc. 7, Fig. 18.1). D. USNM 534424 (loc. 7, Fig. 18.1). E–G. Holotype of* Scaphites corvensis *Cobban, l952, USNM 106755, USGS Mesozoic loc. 20939, Cody Shale, Montana. E. Left lateral view. F. Ventral view of the hook. G. Ventral view of the shaft. All figures X1.*

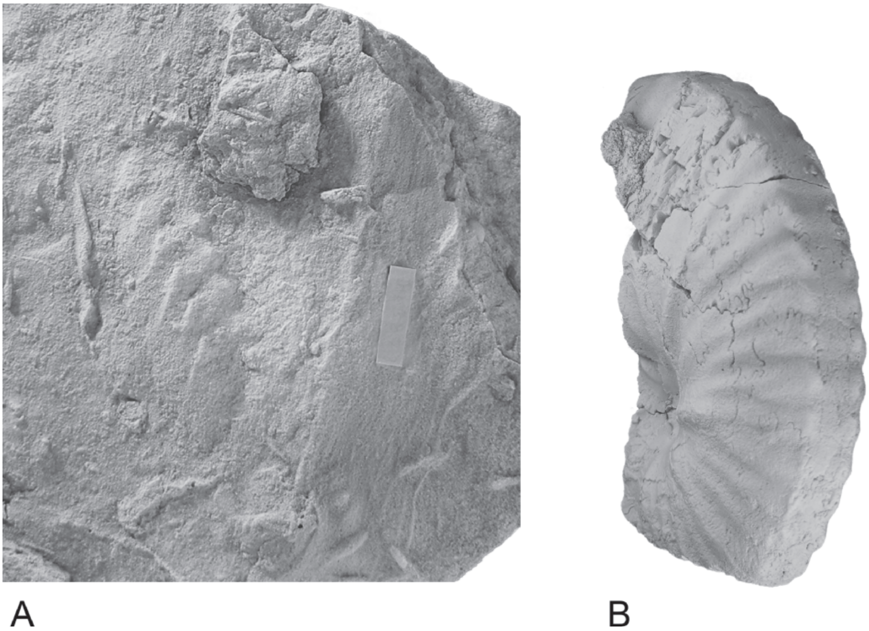

Fig. 18.7 *A. Touch mark, USNM 534425, from a sandy bed in the Floweree Member of the Marias River Shale, Montana (loc. 3, Fig. 18.1), assigned to* Metoicoceras mosbyense *Cobban, 1953, because this is the only species of* Metoicoceras *known from this unit. B. A specimen of* M. mosbyense*, USNM 534426, photographed obliquely for comparison, to show the flattened venter bordered by ventrolateral clavi, USGS Mesozoic loc. 21487, Mosby Sandstone, eastcentral Montana. Both figures X1.*

impression of the ventrolateral tubercles and serrated keel. In Fig. 18.17E, the impression of the tubercles and keel is smaller, reflecting a specimen at an earlier stage of ontogeny. These roll marks perfectly match those produced experimentally by Dzułynski and Sanders (1962), using specimens of *C. woollgari*.

Many ammonite touch marks are also associated with scour and tool marks of unknown origin. These marks may have formed before, after, or at the same time as the ammonite touch marks. Such marks are present, for example, in the Ferdig Member of the Marias River Shale (Figs. 18.5, 6A–D) and the Turner Sandy Member of the Carlile Shale (Fig. 18.21). Other structures may represent burrows that formed at the interface between the mud and the overlying sediments (Fig. 18.5A).

4 Discussion

Ammonite touch marks record the impact of the shells as they bounced and rolled on a firm mud bottom in relatively shallow water. The impressions are preserved on the basal surfaces of siltstones and fine sandstones. The waterlogged shells were

Fig. 18.8 *Touch mark, USNM 534427, showing five straight, narrow, closely spaced ribs, from the upper part of the Dakota Formation near Delta in westcentral Colorado (loc. 13, Fig. 18.1). This impression was made by a large ammonite such as the middle late Cenomanian species* Dunveganoceras conditum *Haas, 1951 (Fig. 18.9B), although this species has not been recorded in Colorado west of Pueblo.*

probably resuspended and carried along by bottom currents associated with storms. As the storms subsided, the ammonites were "the first particles to touch bottom, so that their markings could be immediately cast by the sand, in whose suspension they had been transported" (D. Seilacher, 2005, personal communication).

This scenario requires a substrate firm enough to retain impressions of the shells. The firmness of the bottom may have been due to the cohesive properties of the sediments, perhaps related to the presence of bacterial films or mucus. The

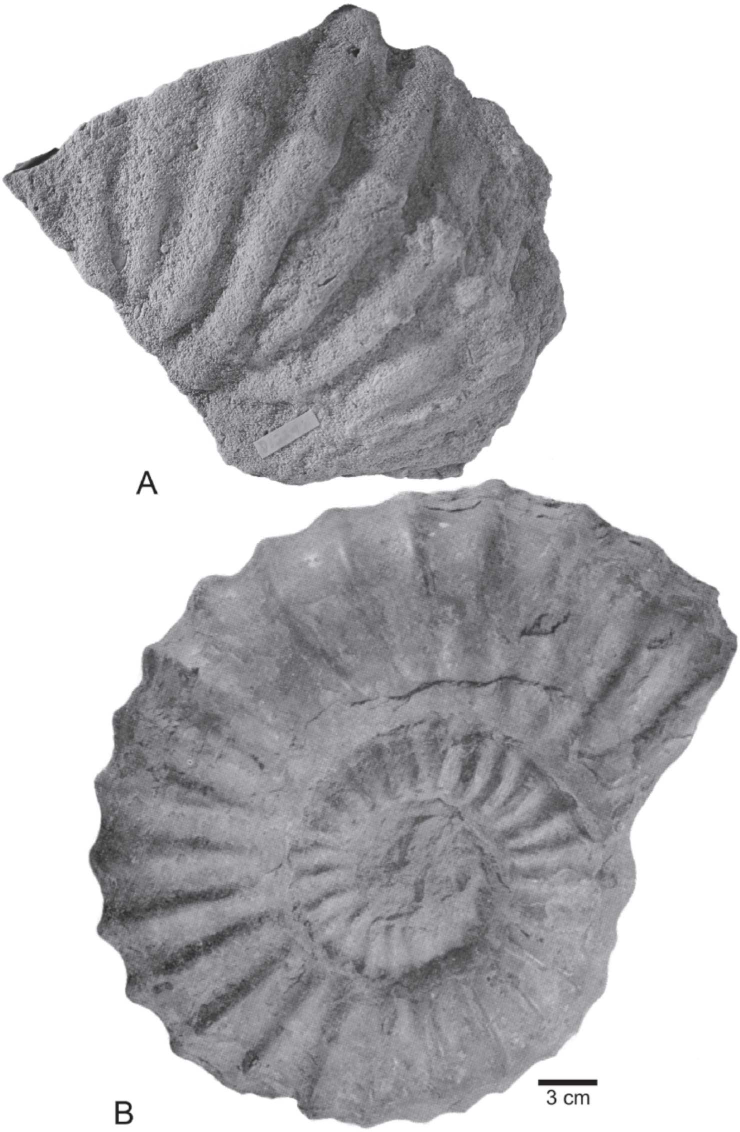

Fig. 18.9 *A. Touch mark, USNM 534428, from the Hartland Shale Member of the Greenhorn Limestone near Pueblo, Colorado (loc. 15, Fig. 18.1), showing fairly closely spaced ribs bearing inner and outer ventrolateral tubercles, suggesting the outer whorl of the phragmocone of an adult specimen of* Dunveganoceras conditum *Haas, 1951, which is the only ammonite like it known from this stratigraphic unit. X1. B. Paratype of* D. conditum*, AMNH 27686, left lateral view, illustrated for comparison, Frontier Formation, T39N R83W, Wyoming. X 0.33.*

ammonite impressions were subsequently covered by the sediments entrained in the current. Afterward, the bottom must not have experienced any significant erosion that would have removed the impressions, or any large-scale bioturbation that would have obliterated them.

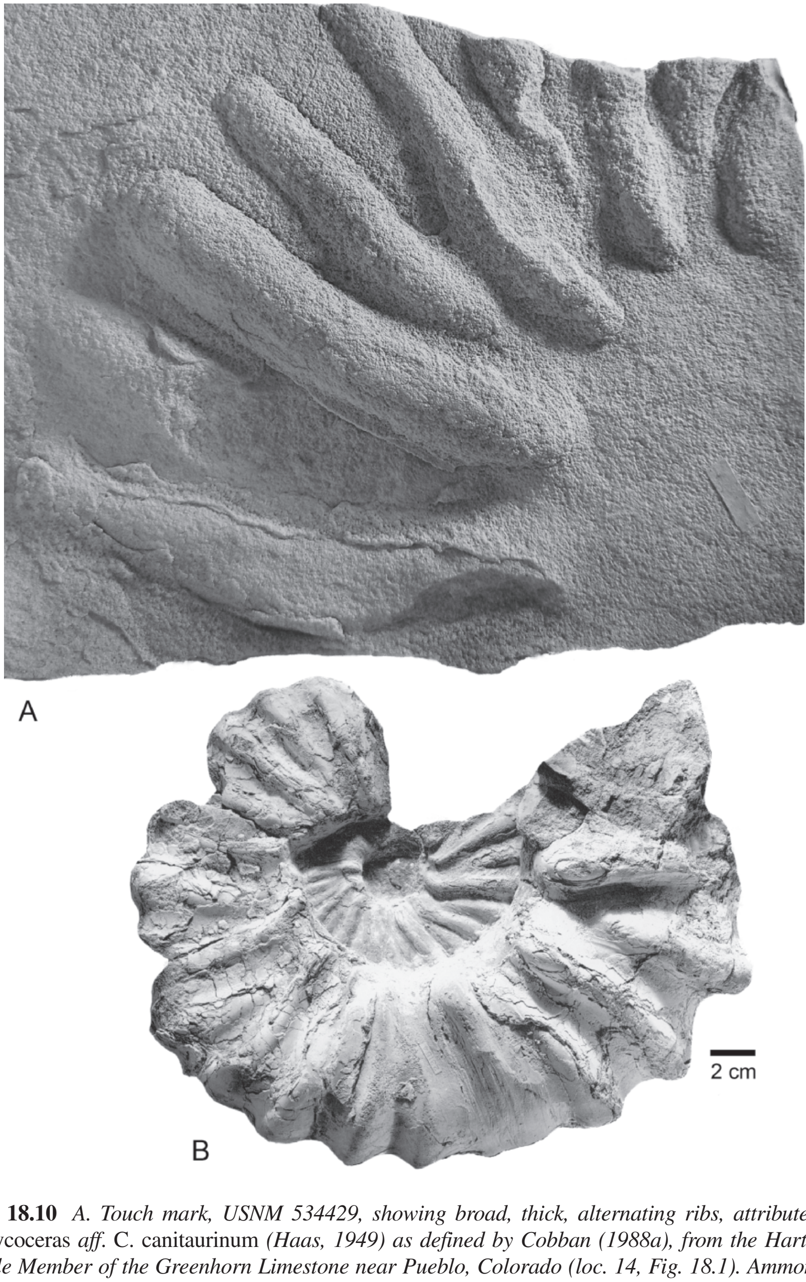

Fig. 18.10 *A. Touch mark, USNM 534429, showing broad, thick, alternating ribs, attributed to* Calycoceras *aff.* C. canitaurinum *(Haas, 1949) as defined by Cobban (1988a), from the Hartland Shale Member of the Greenhorn Limestone near Pueblo, Colorado (loc. 14, Fig. 18.1). Ammonites in the underlying Lincoln Member include* C. canitaurinum. *X1*. B. Calycoceras *aff*. C. canitaurinum*, USNM 376912, right lateral view, illustrated for comparison, USGS Mesozoic loc. 23154, Frontier Formation, Wyoming (Cobban, 1988a: pl. 5). In central Wyoming,* Calycoceras *aff*. C. canitaurinum *occurs in the Frontier Formation just above* C. canitaurinum*, as at Pueblo. X 0.33.*

Fig. 18.11 *Roll mark collected as float, USNM 534430, from the Lincoln Member of the Greenhorn Limestone near Pueblo, Colorado (loc. 16, Fig. 18.1). Several species of acanthoceratid ammonites could have made this type of roll mark. The only acanthoceratid ammonites recorded from the Lincoln Member in the Pueblo area are* Acanthoceras amphibolum *Morrow, 1935,* Calycoceras canitaurinum *(Haas, 1949), and* Tarrantoceras *sp. (Cobban and Scott, 1972; Sageman and Johnson, 1985; see fig. 18.12B, C). Of these,* Tarrantoceras *is the most likely candidate, but none of the specimens of Lincoln age is known to be large enough to have produced a roll mark of this size. X1.*

The ammonite impressions reflect the imprint of a curved surface on a flat bottom and as a result, do not always faithfully record the ornamentation. In addition, depending on the fragmentation of the shell, the strength and direction of the current, the firmness of the bottom, and the nature of the contact (resting, dragging, skipping), the impressions can be indistinct or distorted.

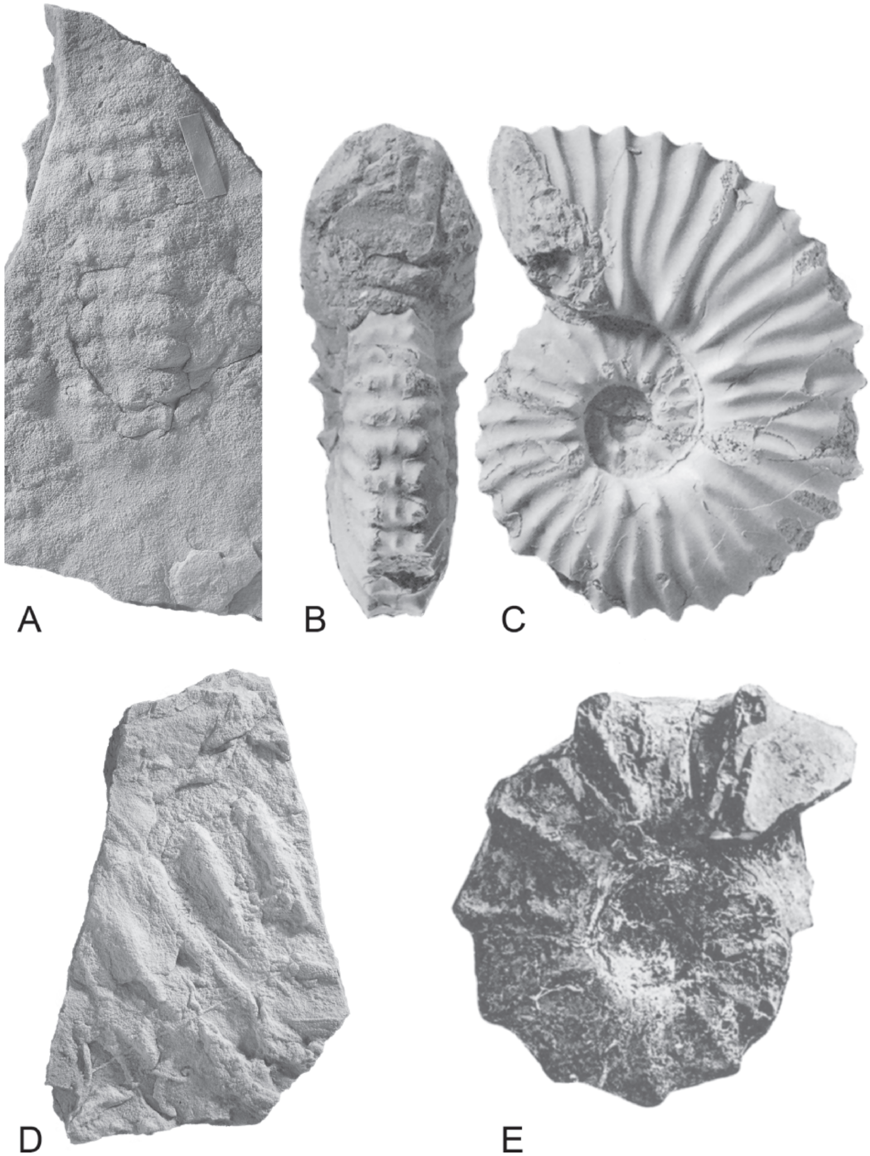

Fig. 18.12 *A. Roll mark of an acanthoceratid ammonite, USNM 534431, such as* Tarrantoceras *Stephenson, 1955 (loc. 24, fig. 18.1). B, C. Holotype of* Tarrantoceras sellardsi *(Adkins, l928), USNM 400760, illustrated for comparison, USGS Mesozoic loc. D12626, Tarrant Formation, Texas (Cobban, 1988b: pl.1, Figs. 6, 7). B. Ventral view. C. Right lateral view. D. Touch mark, USNM 534432, attributed to* Acanthoceras alvaradoense *Moreman, 1942 (loc. 23, Fig. 18.1). This ammonite occurs a little below the Marker bentonite bed at other localities in New Mexico. E. Acanthoceras* alvaradoense*, left lateral view, illustrated for comparison, Tarrant Formation, Texas (Moreman, l942: pl. 32, Fig. 6). All figures X1.*

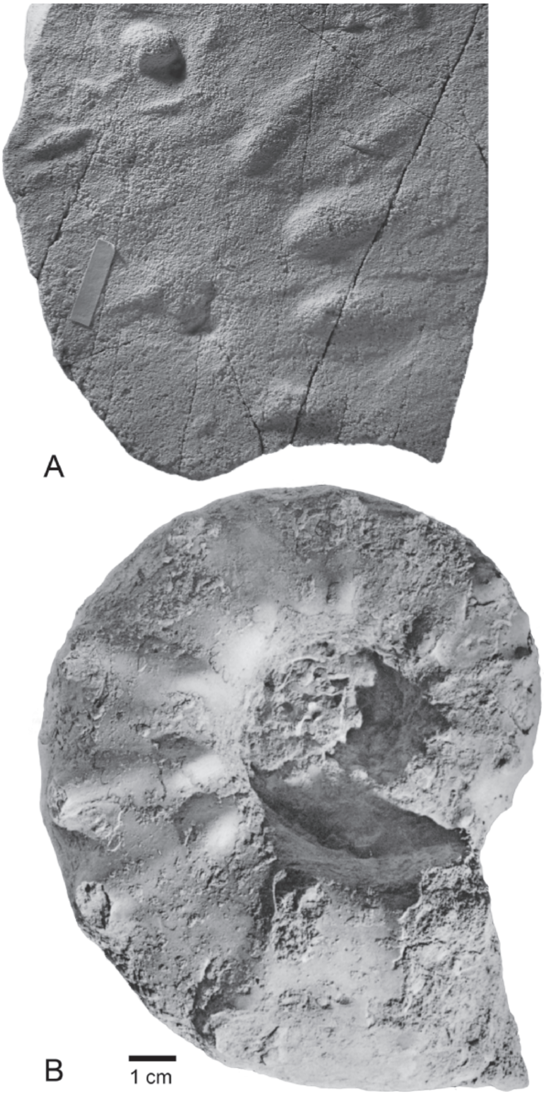

Fig. 18.13 *A. Touch mark, USNM 534433, attributed to* Pseudaspidoceras flexuosum *Powell, 1963, from the* P. flexuosum *Zone in the Mancos Shale of southwestern New Mexico (loc. 22, Fig. 18.1; Cobban et al., 1989: 64). The wide umbilicus and prominent umbilical tubercles are characteristic of this species. X1. B. Holotype of* Pseudaspidoceras paganum*, Reyment, 1954, C. 47422, right lateral view, illustrated for comparison, lower Turonian, Pindiga, Bauchi Province, Nigeria (Reyment, l959: pl.4, Fig. 1). X0.75.*

Ammonite touch marks can be used to derive information on current direction. The ventral touch marks of the scaphitid ammonites show no preferred orientation (Fig. 18.5A), perhaps implying variable current directions. In contrast, roll marks reveal the current track, but it is difficult to determine up from down current. The longer the shell rolled, the longer the roll mark, and the easier to follow the trace.

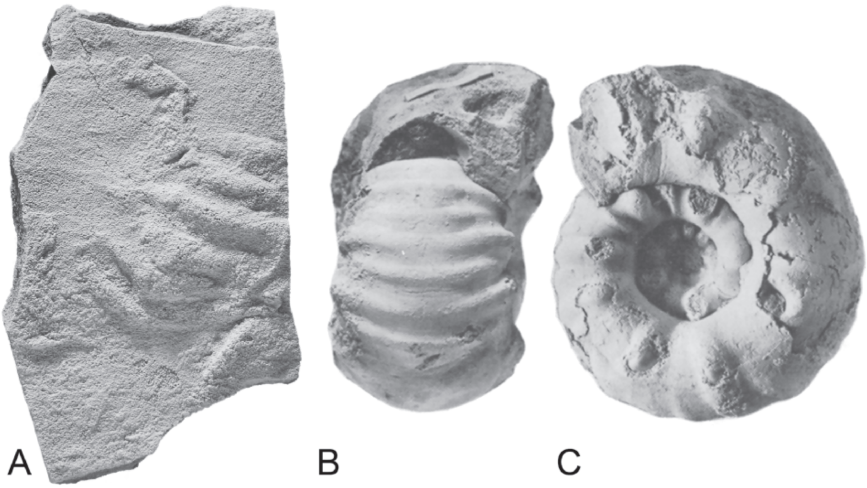

Fig. 18.14 *A. Touch mark, USNM 534434, of the phragmocone of* Fagesia catinus *(Mantell, 1822) (loc. 22, fig. 18.1). Specimens of this Turonian species have been found in calcareous concretions at this stratigraphic level. B, C. A similarly sized specimen of* F. catinus*, USNM 425388, illustrated for comparison, USGS Mesozoic loc. D11009, Colorado Formation, southwestern New Mexico (Cobban et al., l989: Fig. 92GG, HH). B. Ventral view. C. Right lateral view. All figures X1.*

Fig. 18.15 *Touch mark attributed to* Protexanites bourgeoisianus *(d'Orbigny, 1850), USNM 534435, from the El Vado Member of the Mancos Shale of northwestern New Mexico (loc. 18, Fig. 18.1), because there is no other ammonite like it from this stratigraphic unit (see Fig. 18.16B). X1.*

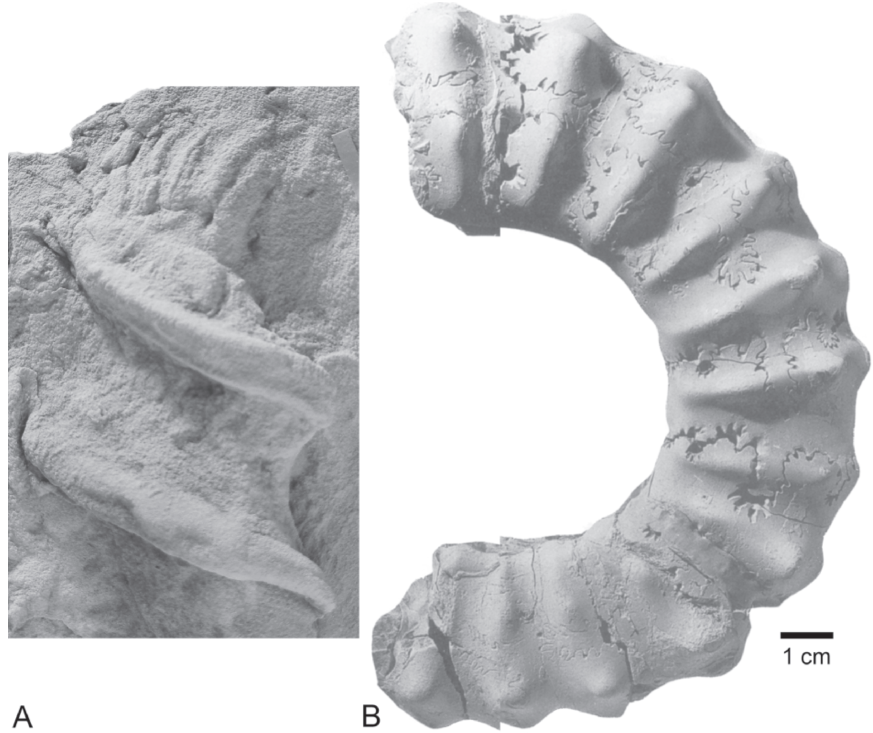

Fig. 18.16 *A. Touch mark attributed to* Protexanites bourgeoisianus *(d'Orbigny, 1850), USNM 534436, from the sandy member of the Niobrara Formation of northeastern New Mexico (loc. 17, Fig. 18.1), a stratigraphic unit that has yielded an upper Coniacian assemblage of the* Scaphites depressus *Zone. The impression is slightly distorted and the ventrolateral tubercles are missing. Note the ribbing of a juvenile nearby, much like the specimen illustrated by Kennedy and Cobban (1991: pl. 8, Fig. 1). X1. B. A specimen of* P. bourgeoisianus*, USNM 433795, right lateral view, illustrated for comparison, USGS Mesozoic loc. 23100, Cody Shale, Wyoming (Kennedy and Cobban, 1991: Fig. 20). X0.75.*

The shape of the component parts of the roll mark may help indicate the initial point of contact between the shell and the seafloor, i.e., the up current end.

The touch marks in the Ferdig Member of the Marias River Shale are remarkable because of their broad geographic distribution, covering an area of several hundred square kilometers in northcentral Montana (Fig. 18.3). They are confined to the upper Turonian *Scaphites corvensis* Zone of the Ferdig Member of the Marias River Shale. This unit consists of silty, noncalcareous shale with lenses of very fine grained sandstone (Mudge, 1972; Cobban et al., 1976; Lemke, 1977).

P.E. Cloud, in an unpublished report from the US Geological Survey (1959), characterized the paleoenvironment of this unit as follows: "a generally quiet marine water body deep enough to be spared strong wave or current action, shallow enough to be within reach of some standing waves, sediments anaerobic enough to

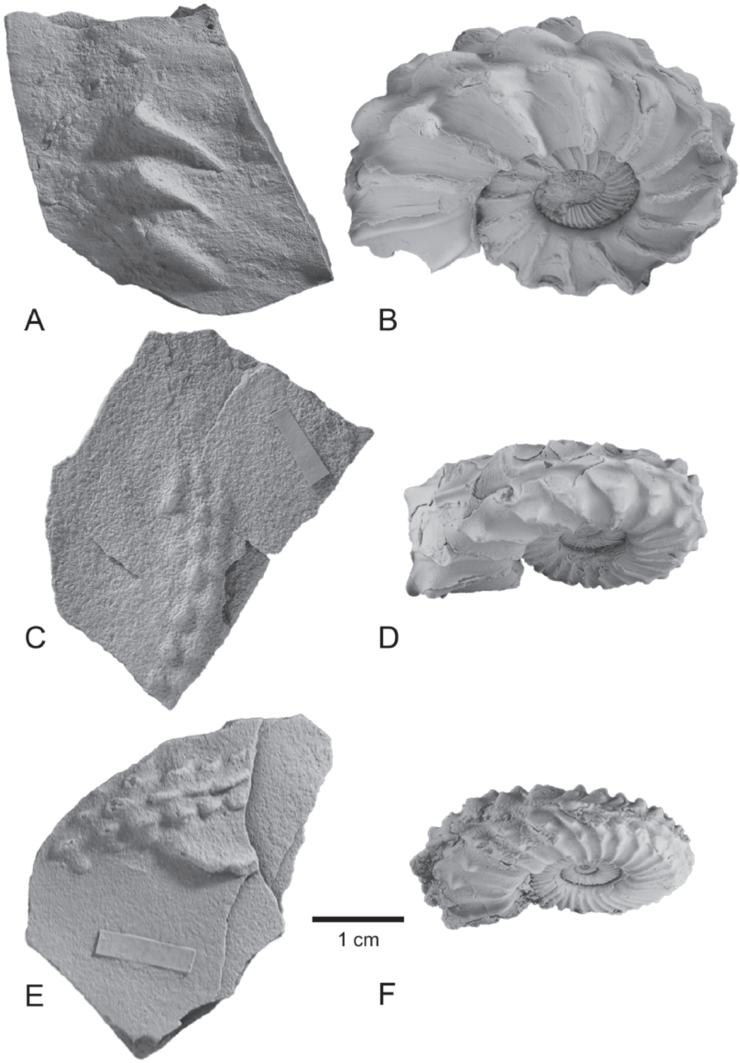

Fig. 18.17 *Touch marks attributed to* Collignoniceras woollgari *(Mantell, 1822). A. USNM 534437, showing three sharply defined narrow ribs bearing inner ventrolateral tubercles, from part of the Mancos Shale of northwestern New Mexico (loc. 19, Fig. 18.1) that contains this species in limestone concretions. X1. B. A similarly sized specimen of* C. woollgari*, USNM 534438, photographed obliquely for comparison, USGS Mesozoic loc. D9896, Carlile Shale, Black Hills area, Wyoming. X1. C. Roll mark, USNM 534439, from the Tropic Shale of southern Utah (loc. 21, Fig. 18.1), that contains this species in limestone concretions. X1. D. A similarly sized specimen of* C. woollgari*, USNM 534440, photographed obliquely for comparison, USGS Mesozoic loc. D3754, Carlile Shale, Black Hills area, South Dakota. E. Roll mark, USNM 534441, from the Mancos Shale, New Mexico (loc. 25, Fig. 18.1). X1.5. F. A similarly sized specimen of* C. woollgari*, USNM 534442, photographed obliquely for comparison, Carlile Shale, Black Hills area, South Dakota or Wyoming. X1.5.*

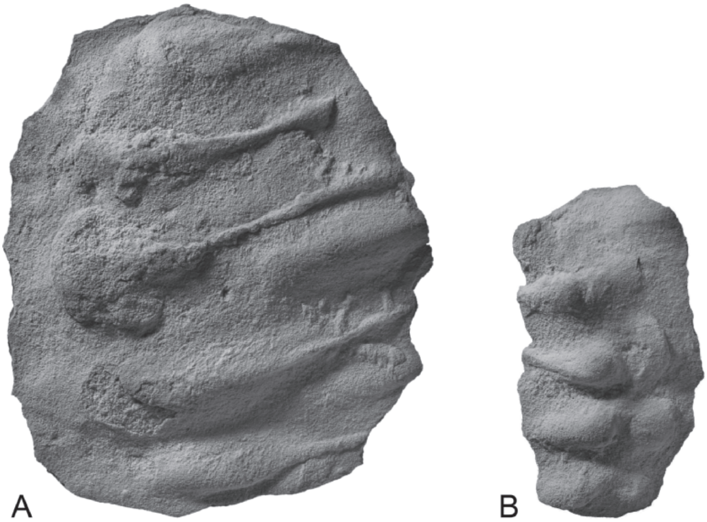

Fig. 18.18 *Touch marks attributed to* Collignoniceras woollgari *(Mantell, 1822), USGS Mesozoic loc. D11022, southwestern New Mexico (loc. 26, Fig. 18.1). A. USNM 534443. B. USNM 534444. Both figures X1.*

limit burrowing activity that would destroy lamination but rich in nutrients for surface feeders, in an area far enough away from a river system for its normal sediments to consist of silt from pulsatory system overflow but near enough to be within reach of heavy and rapid settling-out from occasional flood deliveries."

Most of the touch marks in the Ferdig Member reflect impressions of the venter of the body chamber near the point of recurvature. This implies that the shells were in a nearly vertical orientation with the phragmocone on top. Other impressions reflect the ventrolateral region where the ribs bifurcate. Some of these marks are relatively long, indicating that a broad area of the shell surface contacted the bottom (Fig. 18.5D). Fragments of actual shells, i.e., steinkerns, are also present at this site (Fig. 18.4), and probably represent the very specimens that made the touch marks.

It is possible that the touch marks in the Ferdig Member record a sequence in the taphonomic history of the ammonite shells. For example, the ventral impressions may have been produced during life. Scaphitid ammonites with hook-shaped body chambers were oriented with the phragmocone on top and the hook-like body chamber on the bottom (Landman, 1987). It is conceivable that these animals hovered just above the bottom and occasionally touched it. The ventrolateral and flank impressions may have been produced after death, during progressive stages of shell fragmentation and waterlogging. The steinkerns represent the final disposition of the empty shells.

On the other hand, these ammonite touch marks are also associated with tool marks of unknown origin. It is perhaps more parsimonious to argue that all of these impressions simply reflect transport of waterlogged shells and other debris during

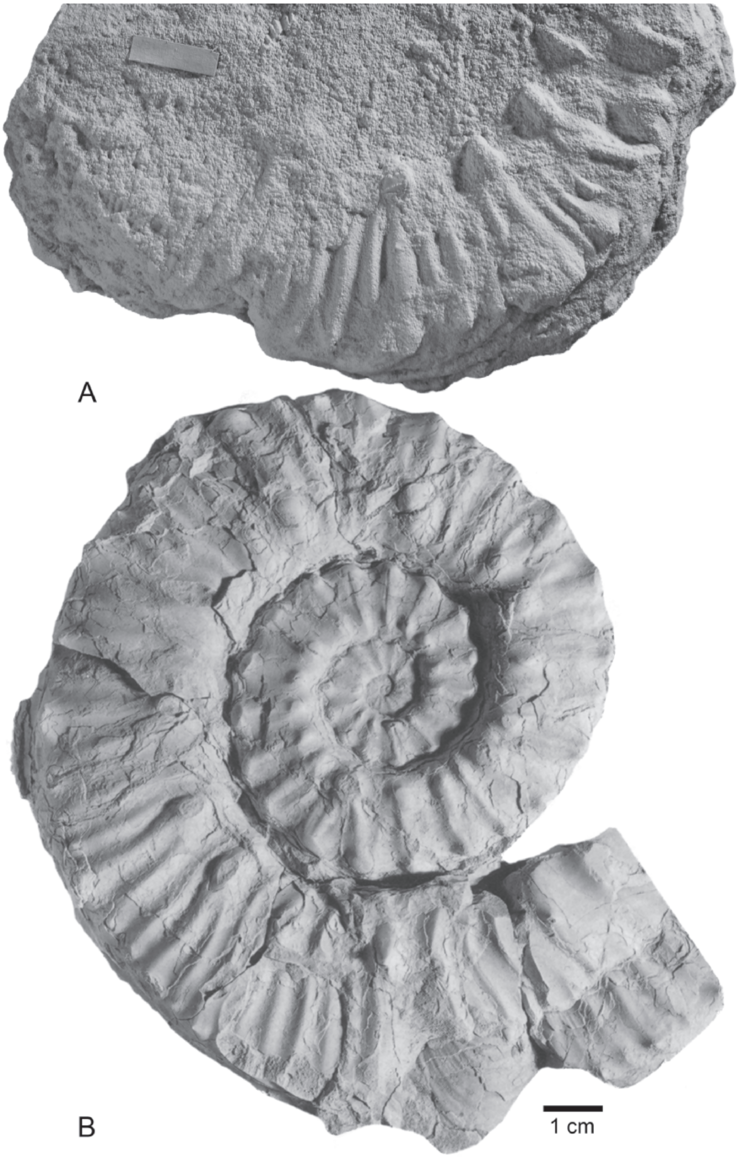

Fig. 18.19 *A. Touch mark, USNM 534445, attributed to* Prionocyclus novimexicanus *(Marcou, 1858) (loc. 20, Fig. 18.1). This unusual and rare preservation clearly shows an ammonite that briefly rested on its side. X1. B. A similarly sized specimen of* P. novimexicanus*, USNM 498417, right lateral view, illustrated for comparison, USGS Mesozoic loc. 21191, Carlile Shale, Butte County, South Dakota (Kennedy et al., 2001: Fig. 99F). X0.85.*

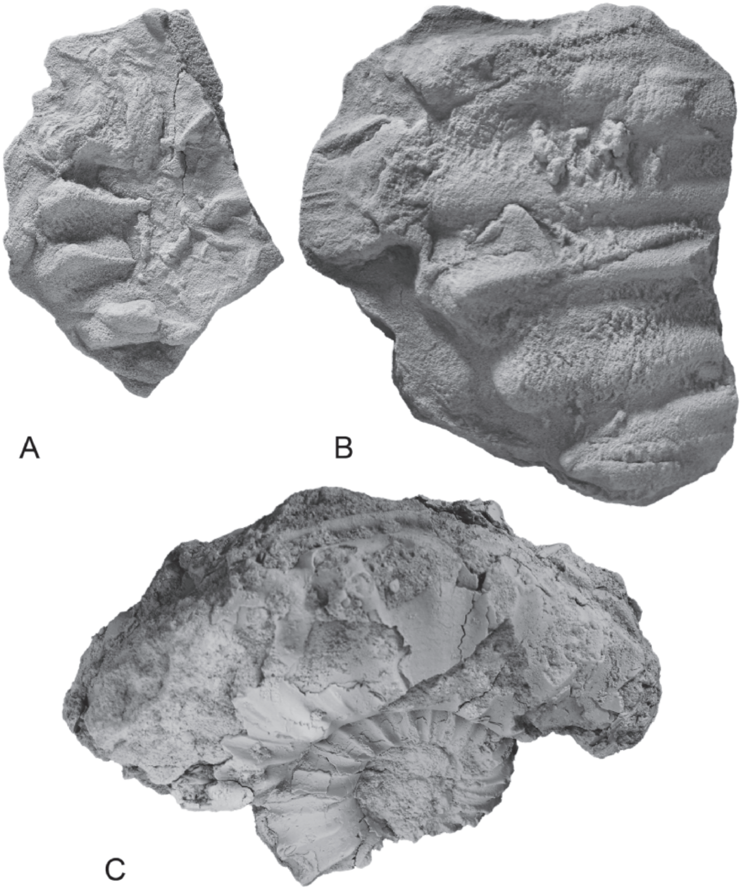

Fig.18.20 *A, B. Touch marks from the middle Turonian part of the Mancos Shale (loc. 12, Fig. 18.1) of northwestern Colorado attributed to* Prionocyclus hyatti *(Stanton, 1894) because this is the only prionocyclid ammonite known from the basal 3 m of the Frontier Sandstone Member in this area. A. USNM 534446. B. USNM 534447. C. A similarly sized specimen of* P. hyatti*, USNM 534448, photographed obliquely for comparison, USGS Mesozoic loc. D14365, Semilla Sandstone, New Mexico. All figures X1.*

periodic storm activity. The extent of waterlogging may have influenced how easily the shells were resuspended, and the kinds of impressions that they made.

5 Conclusions

Touch marks provide a window into the taphonomic history of ammonite shells. If the shells still retained some buoyancy, they would have behaved like lightweight materials, bouncing and skipping on the seafloor. If they were completely waterlogged, they could have been resuspended by bottom currents.

Fig. 18.21 *Touch mark attributed to* Prionocyclus wyomingensis *Meek, 1876, USNM 534486, from the Turner Sandy Member of the Carlile Shale of southwestern South Dakota (loc. 27, Fig. 18.1). X1.*

The formation of touch marks depended on a number of factors related to the ammonites and the paleoenvironment including: (1) the shape of the ammonite shells – inflated or compressed; (2) the kind of ornamentation – keels, spines, ribs, tubercles, or clavi; (3) the state of preservation of the shells – whole or fragmented; (4) the degree of waterlogging of the shells, which is directly related to the amount of residual buoyancy; (5) the strength and direction of the currents; (6) the nature of the contact – dragging, bouncing, or rolling; and (7) the suitability of the bottom sediments to take an impression. After the formation of the impressions, they were immediately cast by overlying silts and fine sands. Subsequently, the bottom could not have experienced major episodes of erosion and bioturbation or the marks would have been completely erased.

Conditions for the formation and preservation of ammonite touch marks seem rare, but the broad geographic distribution of the facies containing scaphitid touch marks in the Ferdig Member of the Marias River Shale of Montana implies that these conditions occasionally prevailed over wide areas. The absence of ammonite touch marks in strata in the US Western Interior above the middle Santonian, on the other hand, suggests that such conditions were not present in this region during the later part of the Cretaceous Period.

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