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On the Trail of Cretaceous Dinosaurs

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British Columbia is a province rich in fossils. During the Mesozoic Era (which lasted from 250 million years ago to sixty-five million years ago), it was a place where millions of dinosaurs lived. Nevertheless, only a handful of dinosaur bones have been recovered from the province. This fact is surprising considering that the next province, Alberta, is one of the richest areas in the world for dinosaur fossils.

In truth, the record of dinosaur bones from British Columbia is virtually non-existent. In 1979, however, a small display in the offices of Crow's Nest Industries Ltd. in Fernie yielded an unexpected find. In a display of coal pebbles – inclusions found within coal seams – was part of a single toe bone of an ornithopod, or bird-footed, dinosaur. The bone (Figure 12.1) is black and was already water-worn before deposition, so it is not surprising that it was thought to be a stone. Many layers of coal are mined in the Fernie region, and the bone could have come from any one of the uppermost Jurassic to Lower Cretaceous seams. Because the specimen is water-worn and incomplete, it is difficult to identify with certainty. The articulating surface is smoothly concave, suggesting that it is the first phalanx of the finger or toe. It most closely resembles the first phalanx of the fourth (index) finger of *Camptosaurus,* but this identification is tentative. There are also rumours that in 1930 Charles M. Sternberg collected a few bones of an ornithopod along the Pine River of northeastern British Columbia. Yet he did not mention this discovery in his field notes, and the whereabouts of such specimens is unknown. So, at this time the report cannot be confirmed.

Few Bones, Many Footprints

Why are there so few dinosaur bones known from British Columbia? After all, there are extensive Mesozoic terrestrial deposits in British Columbia, and the equivalent beds across the border in Alberta have produced a plethora of dinosaurs. There are several reasons for the disparity. During

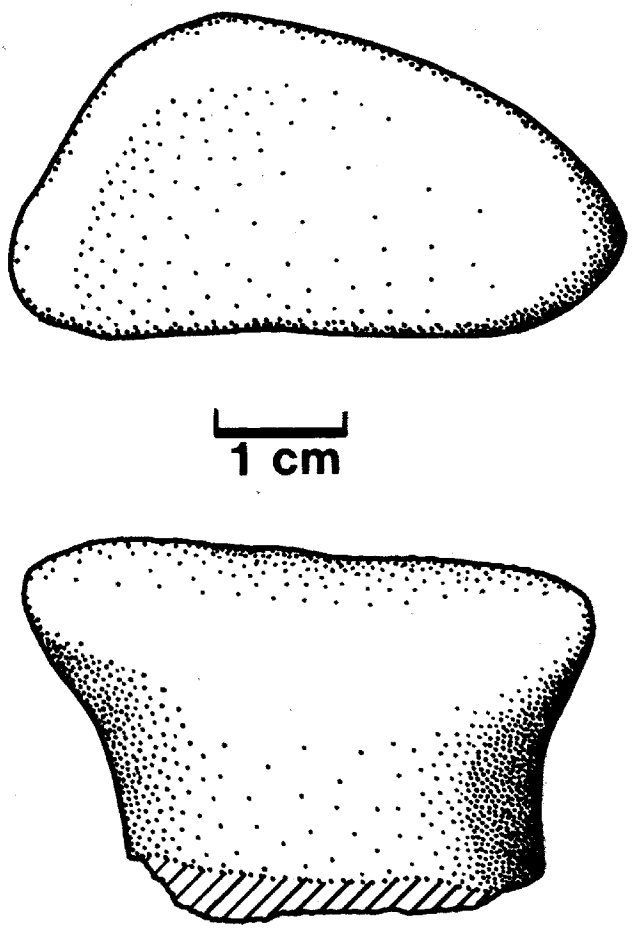

Figure 12.1 **Fossilized toe element of ornithopod dinosaur found in southeastern British Columbia**

Mesozoic times, much of the interior of North America was covered by an inland sea that at times extended from the Gulf of Mexico to the Arctic Ocean. As mountain ranges were pushed up in what is now British Columbia, wind and water erosion started tearing the mountains down. Most of the eroded sediments were carried by rivers and streams east to the sea, where they were deposited on the coastal plains and deltas of Alberta. Bones and even whole carcasses of dinosaurs were buried in the river-borne sands and muds, greatly increasing their chances of preservation as fossils. Furthermore, sediments were deposited in this region so rapidly that there was little opportunity for the development of long-standing marshes and swamps. Although marshy environments are good for the formation of coal deposits, they create acidic ground water that destroys bones before they can fossilize. Thus conditions were ideal in Alberta for the fossilization of dinosaur bone. In contrast, most of the Interior of British Columbia was being eroded, so there were few opportunities for dinosaur bones to become buried and fossilized.

Much more recently, Mesozoic rocks and fossils were re-exposed in Alberta when younger sediments were scraped off by glaciers. Further erosion by the glacial meltwaters cut huge channels into the rocks and created the badlands of southern Alberta. The modern semi-arid climate is not conducive to heavy plant growth, so the rocks remain exposed. This combination of effects greatly facilitates the discovery and recovery of fossils. In contrast, the heavily vegetated, often mountainous regions of British Columbia make it difficult to find dinosaur fossils, even if they are present.

Nonetheless, although British Columbia has not yet yielded many dinosaur bones, the province has long been known as the best source in Canada for dinosaur footprints and trackways. The kinds of conditions required for the preservation of footprints are usually different than the requirements for preservation of bone. Thus, although the coastal plain deposits in Dinosaur Provincial Park, Alberta, have produced millions of fossilized teeth and bones, only two footprints have been identified and collected to date. Conversely, although low-lying wet regions do not permit the fossilization of bone, the wet muds, slow water currents, and gentle accumulation of sediments offer the ideal conditions for preservation of footprints. It is therefore not surprising that the best footprint sites in the United States, China, Korea, and other parts of the world have produced few, if any, dinosaur bones. Dinosaur footprints offer unique and important opportunities to study the lifestyles of these ancient creatures. The remainder of this chapter focuses on the rich dinosaur footprint resources of British Columbia.

The Nature and Study of Tracks

Fossilized tracks are truly remarkable. They record fleeting moments in the lives of animals that lived millions of years ago. As one paleontologist noted, tracks are about the closest thing we have to 'motion pictures' of dinosaurs. The study of fossilized tracks has become a thriving discipline in recent decades, as evidenced by the number of books dedicated to the topic (for example, Lockley 1991). Unlike bones, shells, or other fossil remains of the animals themselves, footprints in trackways record the activities of animals, and sometimes provide information unavailable from skeletons. Sauropod dinosaurs, for example – the huge *Brontosaurus*-type with long necks and tails – were traditionally thought to be aquatic. It was postulated that their gargantuan bodies were simply too massive to be supported on land. This hypothesis has now been disproved on physiological grounds, but the first and best evidence that sauropods were not limited to an aquatic regime came from tracks. Numerous sauropod trackways demonstrate conclusively that these incredible beasts not only spent time on land but also walked upright with all four legs directly

beneath the body and with the tail held aloft instead of dragging along the ground.

Dinosaur tracks have many limitations, however. Paleontologists generally do not attempt to correlate specific tracks with specific dinosaurs. Rather they devise new names, or 'ichnotaxa', for those forms based solely on footprints. The reason for this practice is not surprising – it is difficult to identify the trackmaker with any precision. Feet tend to be rather conservative in dinosaurs, so tracks that appear identical may record the footsteps of quite different animals. To confound matters, the same animal can produce very different kinds of tracks by walking on different surfaces. Deep mud may obscure foot anatomy, while a much harder surface may not record detailed features such as claws. James Farlow, a dinosaur paleontologist and track specialist at Purdue University, has observed ostriches running over a variety of surfaces. He postulates that, depending on the surface, we might even be confusing the clawed tracks of carnivorous dinosaurs with the hoofed tracks of herbivorous forms.

Nonetheless, tracks have much to tell us about dinosaur life and evolution, from walking and running speeds to social behaviour and the turnover of species through time. As it turns out, the numerous dinosaur tracks found in British Columbia are without doubt some of the best and most informative in the world.

Dinosaur Tracks in British Columbia

The earliest record of discovery of dinosaur tracks in North America (and perhaps anywhere) was in 1800, when a large, three-toed footprint was inadvertently ploughed up in Massachusetts by a fellow named Pliny Moody. Dinosaurs were still unknown in 1800, and Moody believed his find to be a track of Noah's raven. The discovery of dinosaur tracks in Canada came more than a century later in 1922, when F.H. McLearn, a Geological Survey of Canada geologist, identified dinosaur tracks along the Peace River Canyon, near Hudson's Hope, British Columbia. At the time, this discovery was the most northerly record of dinosaurs in the world. Following up on this discovery, C.M. Sternberg, one of the greatest collectors of Canadian dinosaurs, ventured to the Peace River site and found over 400 tracks from a variety of dinosaurs (Sternberg 1932). Sternberg named eight new types of dinosaur ichnotaxa, including both bipedal (two-footed) and quadrupedal (four-footed) forms, based on finds from this site alone. Indeed, dinosaur footprints were so common and well preserved in this area that they likely were seen by Alexander Mackenzie when he explored the canyon in 1793.

Unfortunately, we must use the past tense in describing the remarkable Peace River dinosaur tracks. In 1965, with the impending completion of the W.A.C. Bennett Dam, staff of the Royal Ontario Museum

visited the construction site to study and cast numerous footprints. More than fifty tracks were observed by that expedition, tracks that are now covered by the dam itself and by Williston Lake, the largest lake in British Columbia. In the 1970s, construction began on the Peace Canyon Dam, and it became clear that another world-class site would soon be under water. Consequently, the Provincial Museum of Alberta (the parent institution of the Royal Tyrrell Museum of Palaeontology) sent four 'salvage operations,' funded largely by BC Hydro, to record data and collect specimens. In total, more than 1,700 footprints were documented prior to the area being flooded (Mossman and Sarjeant 1983). Today, these tracks are inundated by a lake between the W.A.C. Bennett and Peace Canyon dams. Dinosaur tracks can still be found in the area but not nearly in the abundance known previously.

The dinosaur tracks in Peace River Canyon occur in rocks of Early Cretaceous age (about 115 million years ago). At least nine other dinosaur trackway sites have been found in British Columbia (Currie 1989), ranging in time from the Late Jurassic (about 150 million years ago) to the Upper Cretaceous (about ninety million years ago). Most of these localities occur in the eastern and southeastern part of British Columbia, although there are unconfirmed reports of tracks in the extreme northeastern corner of the province along the Liard River. The tracks at these sites vary from a few footprints to lengthy trackways, and they have been discovered in some extraordinary settings.

Some of the best specimens in British Columbia and elsewhere are found on the ceilings of underground coal mines. Coal is composed of organic remains and is often formed in bog-like environments ideal for the preservation of footprints. Large dinosaur tracks have been known to break away from the ceilings of coal mines, posing a hazard to miners. The oldest known tracks in western Canada come from coal mines near Michel, British Columbia. These prints are relatively small (less than thirty-five centimetres long) and represent tracks from bipedal dinosaurs. As with the tracks found along the Peace River, the Michel tracks represent a dinosaur community that inhabited a lowland coal swamp. Some of the original track specimens, recovered from these mines in the 1940s, are preserved in the collections of the Canadian Museum of Nature and the Royal British Columbia Museum, although the majority apparently have disappeared into private collections. Other footprints have now been found near Fernie and Elkford, although these ones are from the sandstone layers between the coal seams. Today, fossilized tracks are found less frequently in mines due to changes in mining technology.

Another major trackway site occurs in Lower Cretaceous deposits along the Narraway River in eastern British Columbia. These dinosaur tracks, which no longer exist, were in a rather different setting, situated on a

near-vertical cliff face composed of sandstone (Figure 12.2). The sandstone was covered with ripple marks and likely represented an ancient mudflat. There were at least eight trackways, and more than two hundred footprints, all preserved on a single bedding plane. Although numerous tracks on this cliff face were of small, meat-eating dinosaurs, perhaps the most fascinating tracks are of a large, bipedal dinosaur, probably a carnivore as well. The trackway showed that this animal was walking west when it stopped in its tracks (literally), turned to the right, paused briefly, and then proceeded at a right angle to the original path. One can only imagine what would cause a multi-tonne carnivorous dinosaur to change direction so abruptly.

This site was originally described to us by Don Stott of the Geological Survey of Canada in the 1970s, and was examined in 1981. Photographs were shown to staff of *National Geographic* magazine, who decided to send

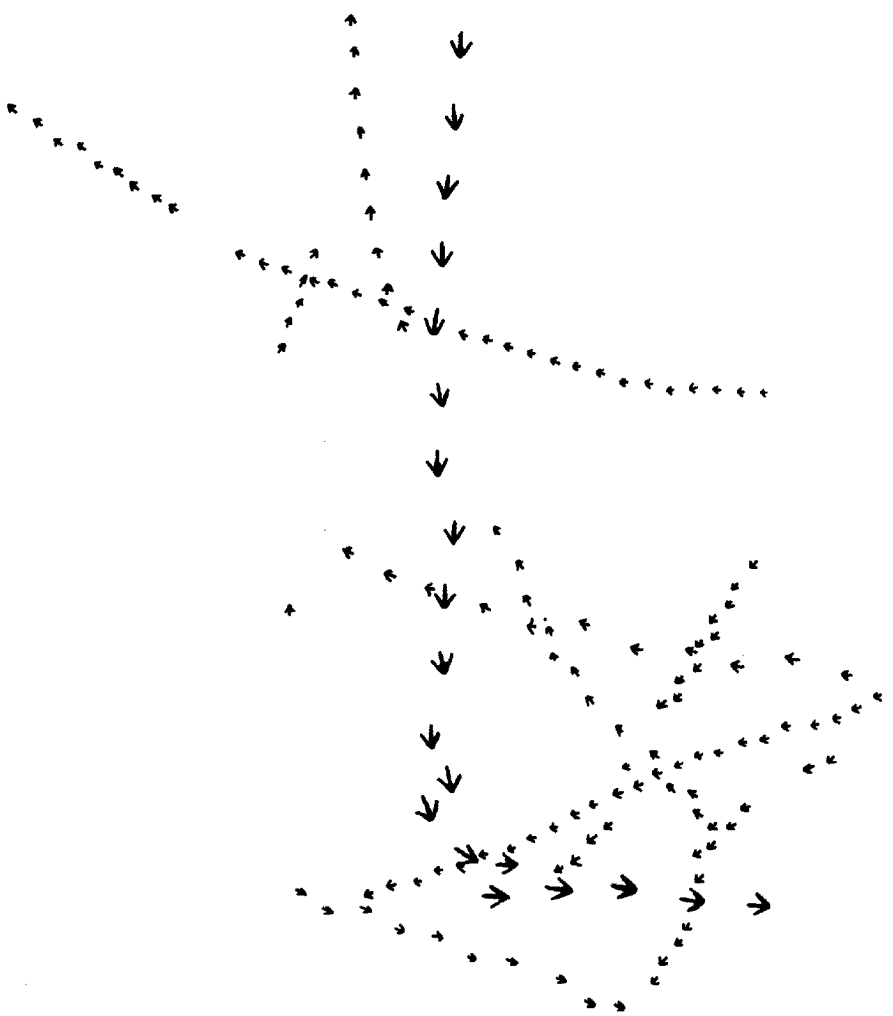

Figure 12.2 **Map of trackway along the Narraway River taken from photographs shot from a helicopter.** Unfortunately, there was no scale on the cliff face, but the largest footprints are about half a metre long.

photographers to take shots suitable for an article on dinosaurs (which subsequently appeared in January 1993). The site is not accessible by road or river, and the only practical way to get to it is by helicopter. After months of planning, a helicopter carried in personnel for the expedition, only to find that the layer with the footprints had slid off the cliff face into the Narraway River. That was an incredible shock, but worse was to come. The backup trackway site for photographs, in Grande Cache, Alberta, collapsed the following night, destroying perhaps another hundred dinosaur tracks. The *National Geographic* crew returned empty-handed, and had to venture as far as Argentina to obtain the equivalent photograph of dinosaur trackways.

Dinosaur Diversity and Distribution

As very few dinosaur bones are known from British Columbia, we must rely on trackways to tell us about the kinds of dinosaurs that inhabited the province (Figure 12.3). The diversity of dinosaurian forms is best documented in the abundant trackways of the Peace River Canyon (Sternberg 1932; Currie and Sarjeant 1979; Mossman and Sarjeant 1983). By far the most common track fossil found to date at this locality is that of a large, bipedal, three-toed animal identified as *Amblydactylus* (Figure 12.4), for which two species have been named. Although originally associated with the primitive ornithopod dinosaur *Iguanodon* (Sternberg 1932), the size and shape of the *Amblydactylus* handprints and footprints indicate that the trackmakers were probably duckbilled dinosaurs, or hadrosaurs (Currie 1983). Well-preserved specimens show impressions made by fleshy webs between the toes. Some footprints show evidence of a large, bulbous pad of soft tissue on the underside of each toe. The tips of all three digits are relatively rounded, indicating the presence of a blunt hoof.

Hadrosaur fossils are extremely common in Upper Cretaceous deposits from around the world. In many regions, these herbivorous ornithopods are the dinosaurs found most frequently, sometimes occurring in massive bone beds containing thousands of individuals. *Amblydactylus* tracks are particularly significant because the oldest hadrosaur bones are of Late Cretaceous age, millions of years younger than the footprints found along the Peace River. Thus the Peace River tracks may represent the earliest record of hadrosaurs, showing that they were alive and well during the Early Cretaceous of British Columbia.

Another dinosaur track commonly found along the Peace River is a bipedal carnivore Sternberg named *Irenesauripus* (Figure 12.3). Like *Amblydactylus*, these tracks are three-toed, but the footprints of *Irenesauripus* are much smaller, with a narrower heel and thinner toes that terminated in sharp claws. Smaller still are the footprints of another biped, *Irenichnites*, represented by several specimens including a slab with five tracks. The

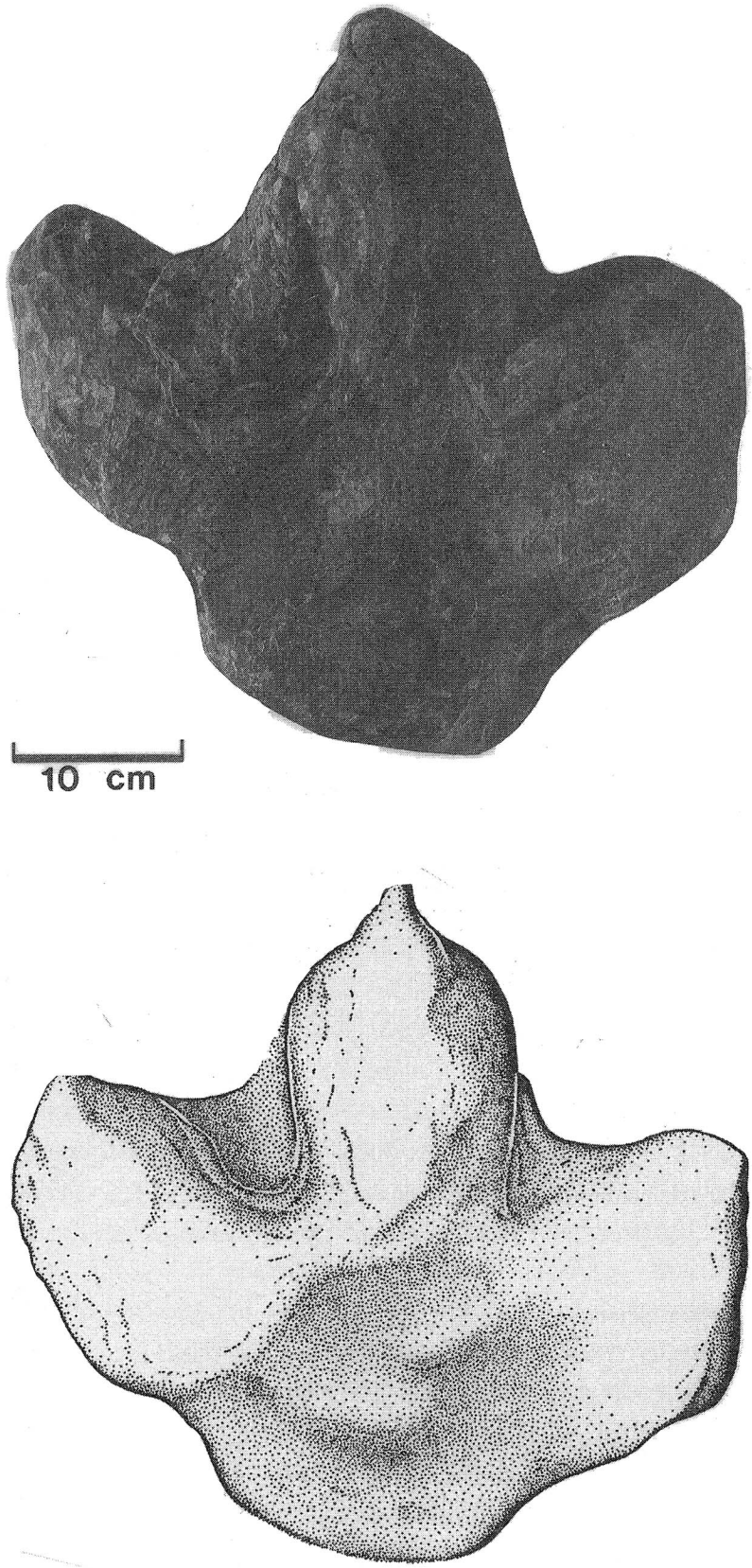

Figure 12.4 **Photograph and interpretive drawing of footprint of *Amblydactylus kortmeyeri* from the Peace River Canyon, British Columbia**
Source: Collections of the Royal Tyrrell Museum of Palaeontology

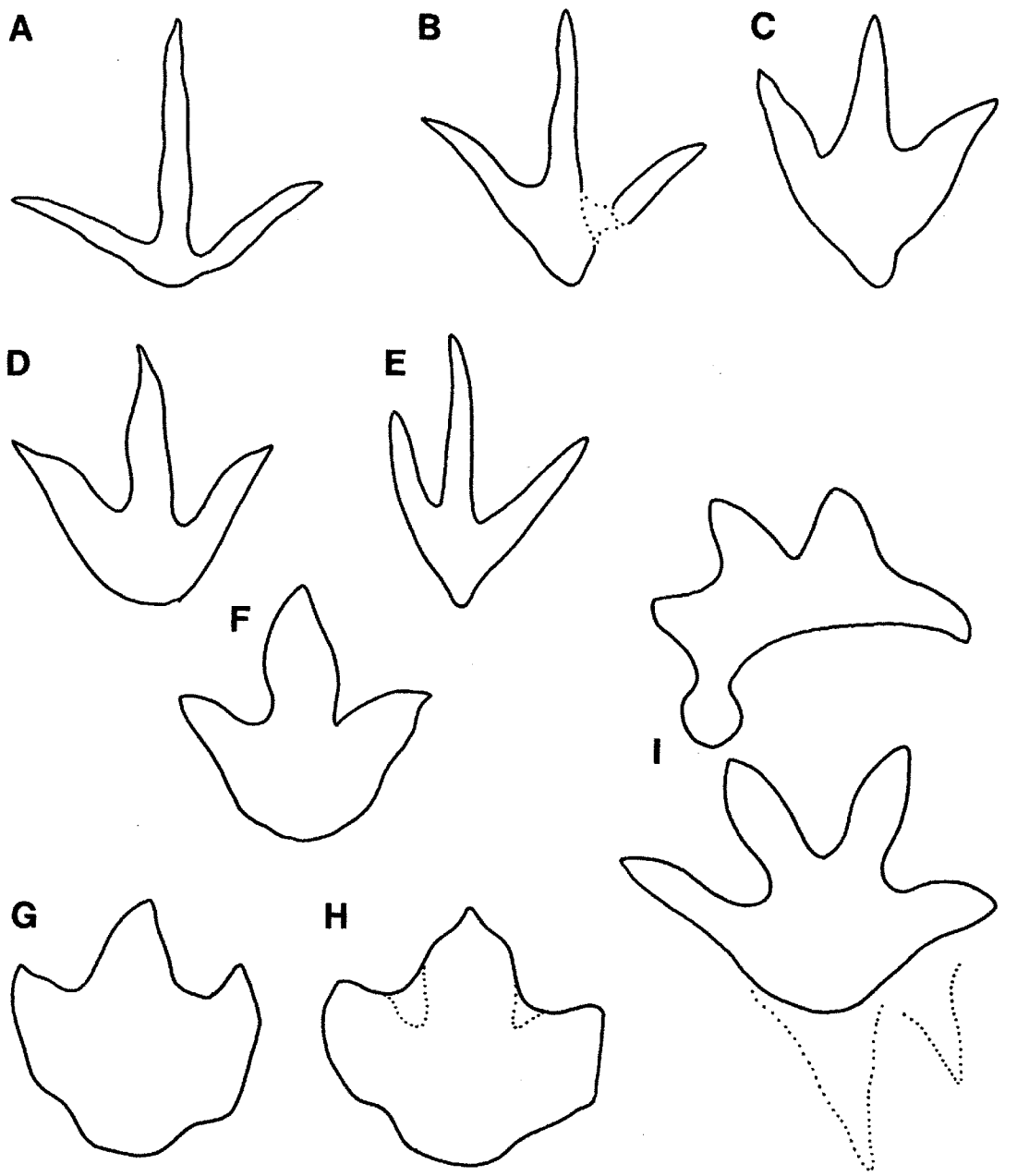

Figure 12.3 **Distinctive types of bird and dinosaur footprints found in British Columbia.** (A) *Aquatilavipes swiboldae,* a bird footprint 4 cm long. (B) *Irenichnites gracilis,* a small theropod track 15 cm long. (C) *Irenesauripus mclearni,* a theropod footprint 33 cm long. (D) *Columbosauripus gracilis,* a possible theropod track 15 cm long. (E) *Irenesauripus acutus,* a large theropod footprint 55 cm long. (F) *Gypsichnites pacensis,* a small ornithopod with a foot 30 cm long (G) *Amblydactylus gethingi,* a 64 cm long track of an iguanodontid or hadrosaur. (H) *Amblydactylus kortmeyeri,* an iguanodontid or hadrosaur footprint 42 cm in length. (I) *Tetrapodosaurus borealis,* left handprint and footprint (the latter is 26 cm long). Dotted lines represent interpolated parts of the prints.

footprints of *Irenichnites* are of questionable origin, but may represent the tracks of a small carnivorous dinosaur. Another distinctive form found in the Peace River Canyon before it was flooded is *Tetrapodosaurus*. *Tetrapodosaurus* ('four-footed-reptile') was a relatively large quadrupedal dinosaur, as revealed by the trackways, which include imprints of both the fore and hind feet (Figure 12.3). Sternberg postulated that the track-maker in this case was a horned dinosaur, or ceratopsian. The detailed anatomy revealed by the tracks, however, and the age of the track itself – younger than any known ceratopsid dinosaurs – suggest that *Tetrapodosaurus* was an armoured dinosaur, or ankylosaur.

Finally, because owls, ostriches, and indeed all birds are believed to be the direct descendants of dinosaurs (and therefore are dinosaurs in the strict sense), we must consider one last set of tracks. In 1979, bird trackways were found in the Peace River Canyon. At the time, this specimen represented the earliest evidence of bird footprints, although some examples from the Jurassic have been reported recently. Like the tracks of small theropod dinosaurs, the bird footprints are tridactylous (three-toed), and the toe impressions are thin. The bird tracks at the Peace River site and elsewhere are small (less than fifty millimetres), and most were likely made by wading shorebirds similar to modern-day plovers.

Notably absent from the fossil footprint assemblages of British Columbia are sauropod dinosaurs. Sauropods have been found in Jurassic rocks from the United States and Asia, and their tracks are known from Lower Cretaceous deposits in Texas. Yet sauropod fossils, either bones or tracks, are unknown from Canada. A land bridge connected Asia and North America for part of the Cretaceous, and the known distribution of sauropods during the Late Cretaceous included both Asia and the United States. So the complete lack of their bones and tracks in Canada is intriguing. As there is no evidence of a geological barrier preventing access by sauropods to northwestern North America during the Cretaceous, we can only assume that they did not venture into Canada for ecological reasons.

Dinosaur Evolution

Throughout their 160-million-year history, dinosaurs were constantly evolving, making substantial modifications in their body plans. Footprints and trackways can provide a measure of the evolutionary changes taking place in the limbs of dinosaurs. If dinosaur trackways from the Lower Jurassic rocks of the Connecticut River valley are compared with those of the Peace River Canyon, it is evident that the earlier animals moved much more slowly and that they frequently dragged the ends of their tails on the ground. The trackways are wider in the Early Jurassic species, which also tended to have more toes than the Early Cretaceous dinosaurs of British Columbia.

The trackway localities of western Canada cover the last eighty million years of dinosaur history. Cretaceous sites tend to show similar types of faunas, dominated by hadrosaurs and large theropods. On the other hand, the uppermost Jurassic sites of southeastern British Columbia have footprints that are more like those of Nova Scotia and parts of the United States. These tracks generally represent much smaller animals, and there is a significant absence of large ornithopods such as iguanodontids and hadrosaurs. Thus the footprint record of British Columbia helps to document the faunal turnover that seems to have occurred at the beginning of Cretaceous times about 145 million years ago.

Dinosaur Behaviour

In the Peace River Canyon, hadrosaur tracks have been found in most of the rock types represented, including sediments deposited in rivers, lagoons, swamps or marshes, and mudflats on the floodplains. These occurrences show that the hadrosaurs walked (and lived) in all these environments. What is perhaps more significant is that the carnivore tracks show the same kind of distribution, leading one to believe that they would not have been averse to following potential prey into the water.

Trackways provide evidence of animal locomotion. No tail drags are associated with any of the trackways, providing strong evidence that Cretaceous dinosaurs held their tails high above the ground. The footprints also show that dinosaurs were efficient walkers that held their legs directly beneath their bodies, and generally walked with long strides on land. Large hadrosaurs seem to have walked on all four legs, because handprints are usually associated with the footprints. This is not always the case, however, as the smaller individuals seem to have walked mostly on their hind limbs.

Many track sites along the Peace River Canyon were made by dinosaurs while in the quiet waters of ponds and placid rivers. In one case, a hadrosaur was walking in a stream, leaving tracks deeply impressed in the mud. As the water became deeper, its stride decreased, and it appears to have been pushing off the bottom with its toes, because the heel of the foot is only shallowly impressed in each track. At one point, the midline of the trackway shifts more than a metre to the right, and several steps later it shifts to the left again. It is difficult to explain these shifts unless the three-to-four-tonne weight of the hadrosaur was being buoyed up in the water. Other lines of evidence support the viewpoint that many of the tracks were made underwater by swimming animals. It is not surprising that only large footprints are present at some localities, because the legs of younger individuals would not have been long enough to reach the bottom and leave footprints.

The orientation of the Peace River tracks, as well as the form of the

trackways, suggests that the ornithopods were somewhat slower and less efficient walkers than the theropods. The ornithopod trackways are 'pigeon-toed,' indicating that the herbivores were rotating their bodies in an arc of about thirty degrees as they walked, swinging their tails from side to side. The theropods, on the other hand, had longer strides, and placed one foot almost directly in front of the other. A formula developed by R. McNeill Alexander uses footprint size and stride length to estimate the speeds of dinosaurs. Applying this formula to the dinosaur trackways in the Peace River Canyon, it is apparent that the hadrosaurs were generally slower-moving than the theropods. On average, hadrosaurs seem to have been walking through the mud at speeds of about six kilometres per hour, compared with theropods at 7.5 kilometres per hour. The highest speed calculated for the ornithopods was only 8.5 kilometres per hour, although it must be kept in mind that all of these animals were walking in mud. One of the Peace River Canyon theropods was calculated to have been running at about fifteen kilometres per hour.

The trackways in the Peace River Canyon provide strong support for the notion that at least some dinosaurs were gregarious. One locality in the canyon preserves the record of nine or ten hadrosaurs *(Amblydactylus)* walking across an ancient flood-plain deposit (Figure 12.5). As they walked, they were actually changing direction. Four of the trackways (C, D, E, and F) follow the same sinuous curves but do not intersect, and seem to have been made by animals that were walking side by side. One interpretation is that these four individuals were walking so close together that when F changed course suddenly, the remaining three animals modified their courses to avoid collision.

Some of the trackways from the Peace River Canyon were made by babies and juveniles. The tracks of one baby *Amblydactylus* are associated

Figure 12.5 **Map of track site in the Peace River Canyon showing multiple trackways attributed to *Amblydactylus gethingi*.** The site shows several animals moving in a single direction and apparently adjusting their paths in unison; the site is therefore good evidence for group behaviour in at least some ornithopod dinosaurs.

with the tracks of another individual of the same size, but no baby footprints were found with juvenile or adult tracks. This is another circumstantial line of evidence supporting the hypothesis that in some species of dinosaurs, the babies did not join the herds of their own species until they were large enough to avoid being stepped on.

More dinosaur tracks will almost certainly be found in British Columbia as more of the province is explored in detail, both above and below ground. Despite the scarcity of dinosaur bones to date, there is tremendous potential for discovering such fossils in British Columbia. While it is true that most Mesozoic terrestrial deposits in the province are well vegetated, there are areas where these rocks are exposed, particularly along river channels. Similarly vegetated areas in Alberta have been explored in recent years, with prolific results; localities discovered near Crowsnest Pass, Edmonton, Hinton, and Grande Prairie are just a few of the newer dinosaur sites. Several rivers draining from British Columbia into Alberta have yielded dinosaur bones along their channels on the Alberta side, while the BC side has never been adequately surveyed for fossils. A number of fossil-rich dinosaur sites have been found in Alaska (also in areas with minimal rock exposures), and it is possible that dinosaurs were migrating between Alaska and Alberta via northeastern British Columbia. Indeed, the probability of finding significant dinosaur localities in this region of the province is considered to be very high. Although the rugged terrain of British Columbia means that the search will be difficult, such efforts are likely to be well rewarded.

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