Flood transported quartzites—east of the Rocky Mountains

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Well-rounded gravel, cobbles and boulders of quartzite have been transported over 1,000 km to the east of their Rocky Mountain source areas. They are found at the tops of mountains, ridges and plateaus, as well as at the bottom of valleys, and are found in deposits ranging in thickness from a thin veneer, or lag, to 5,000 m. Percussion and pressure solution marks are commonly found on the clasts. All of these evidences point to catastrophic, powerful erosion and transport on a subcontinental scale, suggesting that these deposits formed during the Flood.

Quartzite, sometimes called metaquartzite,[1] forms from a quartz rich sandstone which has undergone metamorphism, resulting in the recrystallization of the quartz grains and silica cement.[2]

Extensive outcrops of quartzite layers are found in the Rocky Mountains of northern and central Idaho, north-western Montana and adjacent Canada, predominantly in the Belt Supergroup of the United States and equivalent strata in Canada (figure 1).[3] Softer argillite* (or siltite) outcrops are often found associated with the quartzite outcrops. Figure 2 shows an outcrop of quartzite about 60 km south-west of Salmon, Idaho and figure 3 shows the vitreous* texture of quartzite with an iron patina.*

Due to its hardness, quartzite weathers and erodes very slowly compared to the other geological materials (limestone, sandstone, shale and various metamorphic and igneous rocks) which make up the Rocky Mountains. Consequently, well-preserved, transported, quartzite rocks are found in unlithified* deposits scattered eastward across the Northern Great Plains more than 1,000 km from their indicated sources (as will be discussed below).[4] The clasts range from gravels to large boulders[5] and are almost always rounded or well rounded, indicating water-borne transport.[6] In this report we will use the term 'gravel' in a generic sense to include the larger cobbles and boulders.

Poorly rounded clasts of the underlying rock strata are sometimes found mixed in with quartzite gravels suggesting that the processes that transported the quartzites also eroded and redeposited subjacent* rocks. For example, lozenged-shaped clasts of subjacent sandstones make up almost 5% of the clasts among the quartzites on the Cypress Hills of south-east Alberta.

This paper describes the many occurrences and diverse circumstances in which well-rounded quartzites have been transported east of their Rocky Mountain source areas in the north-western United States. We will divide up the descriptions by areas, starting with the high plains of northern Montana and adjacent Canada. Next, we will briefly describe the high plains of southern and central Montana that we have not extensively explored. And finally we will discuss the quartzite gravels, as well as limestone conglomerates, in south-west Montana, north-west Wyoming and adjacent Idaho. A subsequent paper will document similar occurrences in Washington and Oregon west of the source outcrops. The data from these two areas consistently point to a catastrophic process that is not occurring today, which will be the subject of a third paper.

Important evidence for catastrophic processes include the locations and properties of the quartzites, such as elevation, volume, percussion marks,* pressure solution marks* and iron staining (patina), which provide information on the mechanism of transport. In some cases, the estimated size of the gravel outcrop is only a rough approximation, because of our limited field work. Our maps of quartzite locations are, therefore, of a preliminary nature.

Planation surfaces

A planation surface is a flat or nearly flat erosion surface, the latter defined as '[a] land surface shaped and subdued by the action of erosion, esp. by running water. The term is generally applied to a level or nearly level surface.'[7] Planation surfaces indicate a broad-scale mechanism of significant power to evenly plane-off tilted sedimentary layers including both hard and soft materials (figure 4). The capping of these surfaces by rounded rocks appears to confirm that water currents carrying rock in suspension were the main erosive agent. Pediments are sloping planation surfaces at the edges of mountains and plateaus, as well as in mountain valleys.[8]

The Cypflax Gravels on the plains of Montana and adjacent Canada

In broad terms Montana and the adjacent Canadian high plains are made up of four planation surfaces.[9] Quartzite gravel is found extensively on the planation surfaces of Montana east of the continental divide, southern Alberta and southern Saskatchewan (figure 5). There seem to be two general types of quartzite in this region: (1) a very hard and vitreous variety found mainly in northern Montana and Canada that we have named Cypflax and (2) a less hard and less vitreous variety that is found further south. Cypflax is

* Items with an asterisk are defined in the glossary at the end of this article.

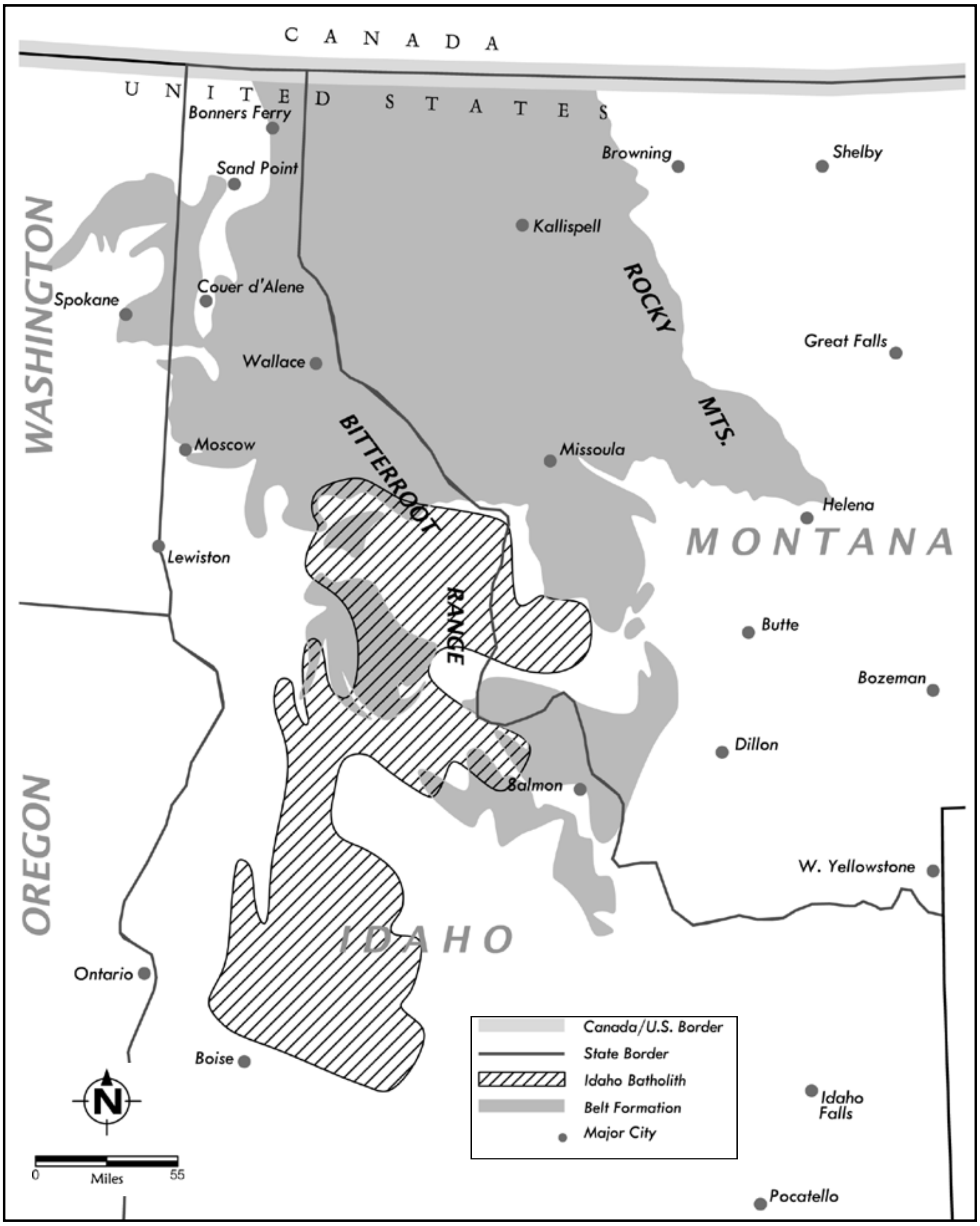

Figure 1. Quartzite sediment outcrop areas in northern and central Idaho and north-west Montana. Idaho batholith in west-central Idaho also indicated.

shorthand jargon for the Cypress Hills and Flaxville gravels that occur mainly on the top two planation surfaces in the area: the Cypress Hills of Canada and the Flaxville Plateaus of north central and north-east Montana.[10,11]

The Cypress Hills planation surface is the highest and is referred to as Bench Number Zero in Alden's classification.[12] The Flaxville plateau or planation surface in north-east Montana is referred to as 'Bench Number 1'. The Wood Mountain quartzite gravels of southern Saskatchewan are at an intermediate altitude between the Cypress Hills and Flaxville levels. Bench Number 2 consists of many small plateaus lower in altitude than the Flaxville surface that are scattered about the high plains. The Fairfield Bench (about 140 km east-west) located north-west of Great Falls, Montana, is a typical example. The eastern part of this planation surface inspired William Morris Davis to construct his popular but now defunct 'cycle of erosion' or 'geographical cycle'.[13] Bench Number 3 is the lowest planation surface of all. In the Great Falls area, Bench Number 3 is a small gravel-capped bench along the southern portion of the Fairfield bench. It was from a gravel deposit on this bench that Klevberg[14] deduced that rapid currents moving in excess of 15 m/sec deposited the gravel.

The Cypress Hills

The Cypress Hills are large, flat-topped erosional remnants that were likely once continuous but have been dissected, probably by the more channelized phase of the Flood or post-Flood glaciofluvial currents (figure 6).[15] They are located in south-east Alberta and south-west Saskatchewan, Canada. They extend approximately 130 km east-west, and in plan view are wedge shaped, being 5 km wide at the western end and about 30 km wide at the eastern end comprising a total area of about 1,090 km^2.[16] The western edge is 1,466 m ASL,* and 300 m above the surrounding plains to the north—which probably represents Bench Number 1—and about 700 m above the surrounding rivers. The most striking feature of the western and central portions of the Cypress Hills planation surface is that they are capped with about 30 m of predominantly well-rounded quartzite gravel (figure 7 and 8)! There is also reworked quartzite gravel that is mostly south of the Cypress Hills, called the 'redeposited Cypress Hills Formation'.[17]

Nearly all the quartzite gravel exhibits a uniform patina of iron oxide (see figure 3). The gravel is massive,* poorly-sorted,* imbricated,* and clast-supported* with a few sand interbeds. Paleocurrent indicators (figure 5)

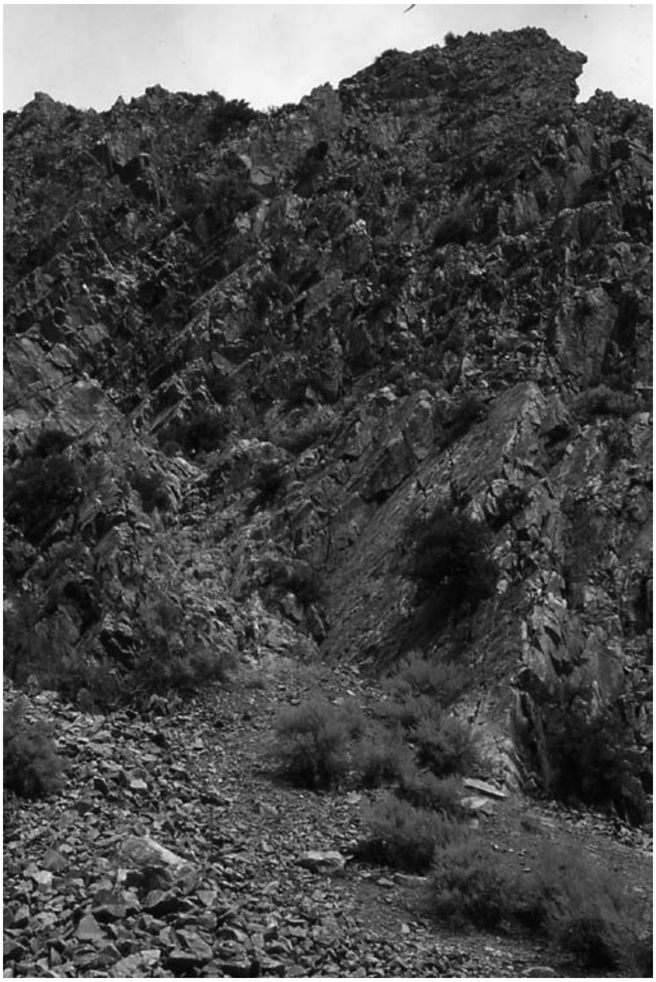

Figure 2. *Thick outcrop of bedded quartzite along Morgan Creek Road, about 7 km from Highway 93, 60 km south-west of Salmon Idaho and 15 km north of Challis, Idaho.*

Figure 3*. Vitreous texture of a fractured quartzite boulder from the top of Red Mountain, northern Teton Mountains. Note the iron patina on the well-rounded surface of the clast (arrow). Quartzites are found among angular limestone clasts. Red Mountain is composed of limestone.*

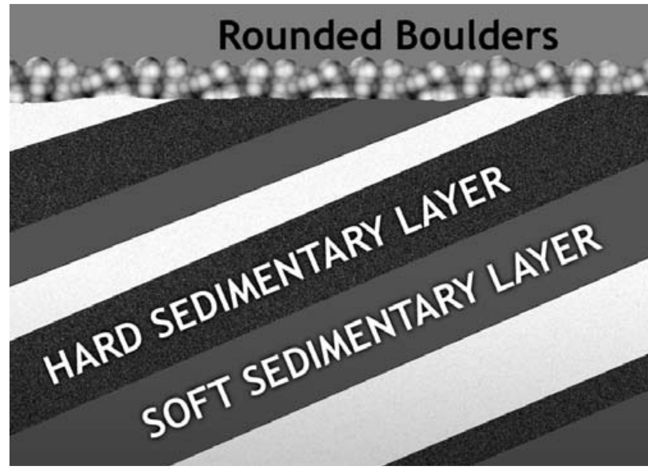

Figure 4. *Diagram of a gravel-capped planation surface on tilted sedimentary rocks that have truncated all lithologies the same amount whether hard or soft (drawn by Peter Klevberg and Daniel Lewis).*

show an average flow direction from the west-south-west. The nearest quartzite sources in that direction are the northern Rocky Mountains of Montana, over 300 km away. However, the lithology of Cypflax indicates that the quartzite likely came from *west* of the continental divide, with some uniformitarian researchers suggesting that the clasts could have come from central Idaho, a further 200 km distant.[18]

About 50% of the clasts on top of the Cypress Hills have percussion marks, while only a few exhibit pressure solution marks. One exceptional boulder that we discovered had very large (4 cm radius) percussion marks (figure 9). Percussion marks on hard quartzite clasts imply very turbulent flow with some clasts hitting each other while briefly in suspension.

The Swift Current Creek Plateau (south of Swift Current, Saskatchewan) about 70 km east-north-east of the Cypress Hills (see figure 5) is considered by some to be an extension of the Cypress Hills,[19] as the quartzites capping this plateau are believed to be the same type as on the Cypress Hills (figure 10). This low-lying plateau is, surprisingly, only slightly glaciated with a thin cover of diamict,* being interpreted as glacial till, in some areas.[20] This probably indicates that there was only one thin ice sheet during the Ice Age in this area.

The Flaxville surface

The Flaxville planation surface extends as a belt of large plateaus within an area 300 km east-west by 80 km north-south in north central and north-east Montana (figure 5).[21] The plateaus generally rise 100 to 200 m above the surrounding plains. It is likely that these plateaus are actually erosional remnants and were once continuous as indicated by concordant surfaces and similar Cypflax on the plateaus. The quartzite gravel on the Flaxville surface varies in depth from about 1 metre to as much as 30 m.

Quartzite gravel on top of the hills in Alberta is generally correlated to the Flaxville gravels.[22] But this correlation is partially based on fossils.[23] If the correlation is true, it indicates that the Flaxville gravel-capped planation surface was much more extensive in the north-south direction, and has been mostly eroded away, leaving behind erosional remnants. The best documented area of these gravel capped hills are the Wintering Hills and the adjacent Hand Hills to the north (25 km east of Drumheller, Alberta), both of which are about 225 m above the surrounding plain (figure 11). About 9 m of quartzite gravel caps the Hand Hills.[24] Many of the gravel clasts have an iron patina, while very few percussion marks were observed (figure 12). This gravel is similar to that on both the Cypress Hills and Flaxville Plateaus.

The Wood Mountain Gravel caps low plateaus in southern Saskatchewan just north of and at a little higher elevation than the Flaxville gravels (figures 13 and 14).[25,26] The quartzites resemble those of the Flaxville Plateau and Cypress Hills.[27] The Wood Mountain upland, which is at an elevation of about 980 m ASL in the west and 875 m ASL in the east, is only about 100 m above the surrounding terrain. The Wood Mountain upland is claimed to be a northern extension of the Flaxville driftless or unglaciated area by some researchers.[27,28] Klassen states:

> ‘The main features of Late Tertiary landscapes are remarkably well preserved over the unglaciated and weakly glaciated parts of the Cypress Hills [top 100 m of western block] and Wood Mountain uplands.[29]
>
> ‘There is no sign of glacial overrunning of the Wood Mountain uplands, as indicated by a lack of glacial features and the *in situ* gravel exposed at the top of the plateau. However, on a field trip to the area we found crystalline erratic boulders, likely from the

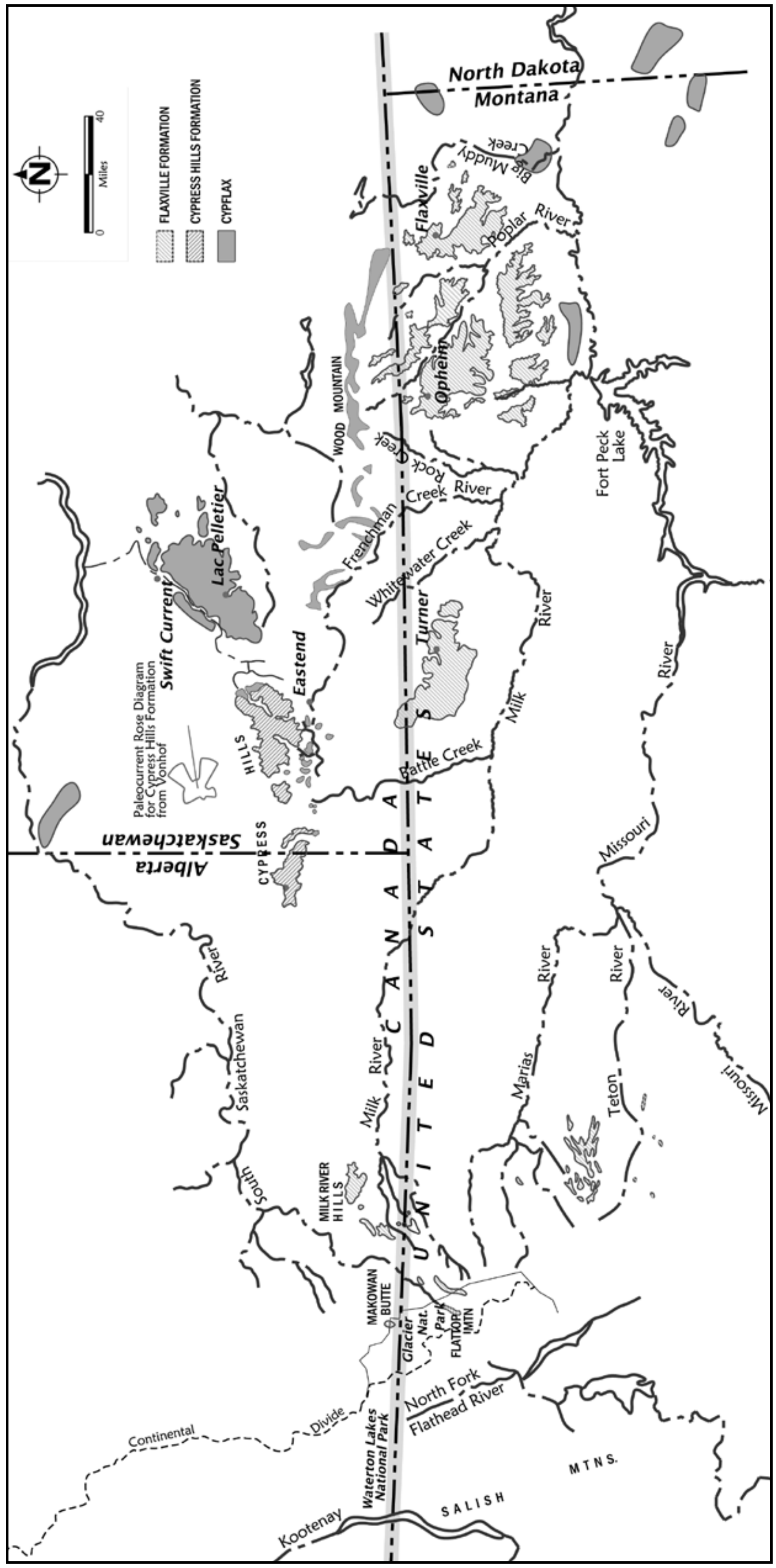

***Figure 5.** Locations of quartzite outcrops on the plains of northern Montana and adjacent Canada, east of the inferred source area located in the northern Rocky Mountains. Diamict, interpreted as glacial till, covers much of the area including most of the quartzite locations. Only the western cypress Hills and the Flaxville plateaus and adjacent Wood Mountain plateau are considered unglaciated.*

Figure 6. *The flat surface on top of the Cypress Hills at Upper Battle Creek. Surface has been partially dissected, likely from glacial meltwater rivers, since large crystalline boulders were found within the valley.* ***7.*** *View north over the edge of the central Cypress Hills at Conglomerate Cliffs.* ***8.*** *The quartzite gravel cap at Conglomerate Cliffs, central Cypress Hills.* ***9.*** *A boulder with percussion marks 4 cm in radius found in the western Cypress Hills, south-east Alberta (head of rock pick is 18 cm long).* ***10.*** *Gravel-capped Swift Current Creek Plateau at Lac Pelletier, Saskatchewan, Canada.* ***11.*** *Gravel cap on top of the Wintering Hills, about 25 km east of Drumheller, Alberta, Canada, approximately 225 m above the surrounding plains.* ***12.*** *Percussion marked and iron-stained boulder from the gravel cap on the Wintering Hills.*

Figure 13. *In situ gravel cap on top of the Wood Mountain Plateau, south central Saskatchewan. This area is part of the driftless area during the Ice Age since there are no signs of glaciation and an ice sheet would have sheared off this gravel.* ***14.*** *Close up of the quartzite gravel in figure 13 showing the planar beds.* ***15.*** *Gravel-capped Two Medicine Ridge (erosion surface) just east of southern Glacier National Park. Part of the same erosion surface can be seen in the distance.* ***16.*** *Alden's Number 2 Bench at the Del Bonita border station, north of Cut Bank, Montana. Notice the flatness of the planation surface.* ***17.*** *The gravel cap of the surface shown in figure 16.* ***18.*** *Gravel-capped planation surface remnant in the Judith Basin west of Lewistown, Montana. Square Butte igneous remnant, 600 m above the plains, is in left background.*

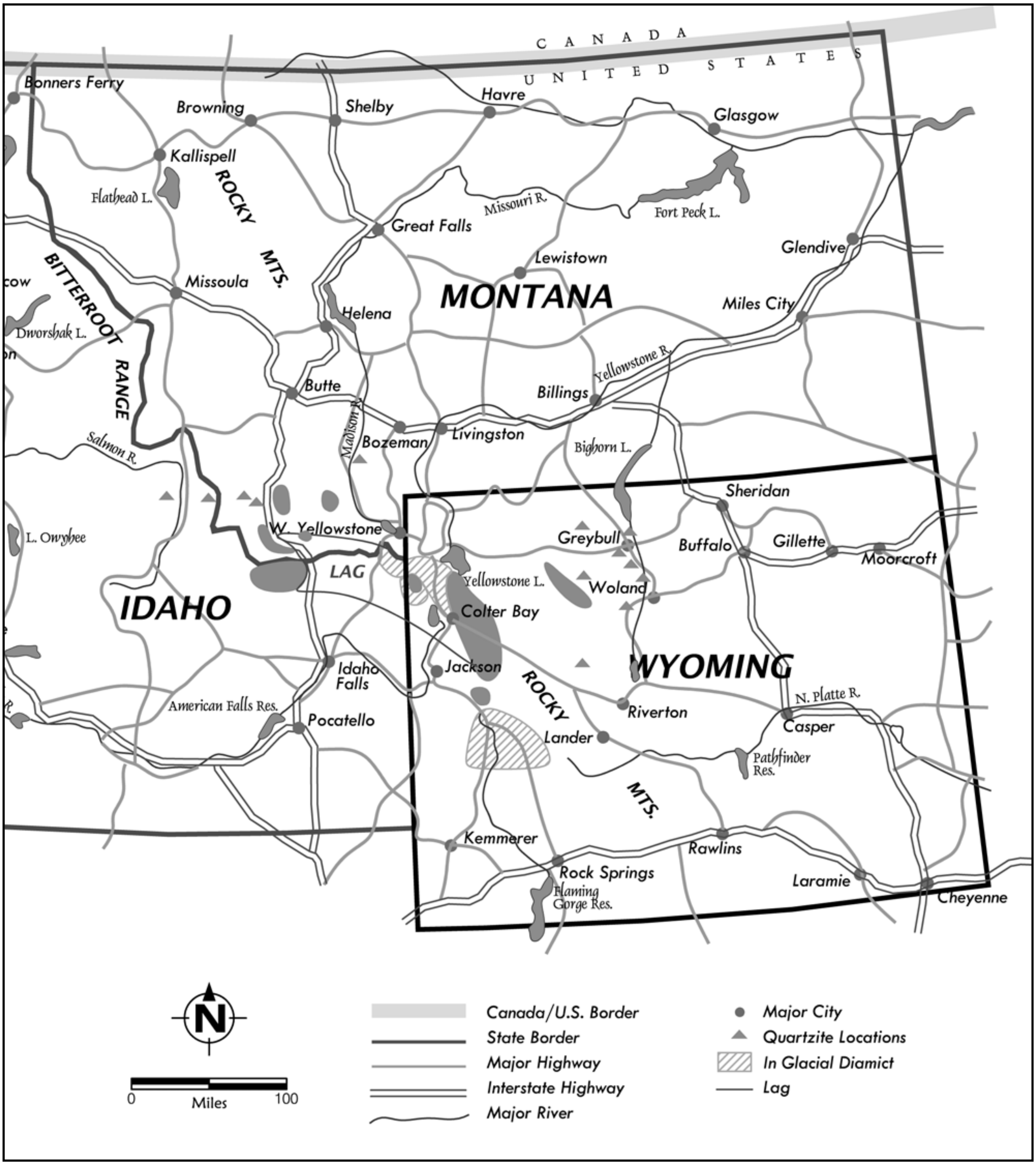

Figure 19. *Quartzite gravel locations in south-west Montana, north-west Wyoming and adjacent Idaho.*

Canadian Shield, lying on the surface of the highest terrain. These crystalline boulders are similar to those found extensively over glaciated parts of northern Montana, Alberta and Saskatchewan. Their existence on top of the "unglaciated" Wood Mountain plateau suggests a different glaciological picture from the uniformitarian surmise for the area. These boulders were likely rafted into place in a pro-glacial lake that briefly covered this unglaciated area during deglaciation.'

On the plains between the plateaus, and north of the Cypress Hills, there are numerous but widely scattered deposits of *in situ* quartzite gravel called the 'Saskatchewan Gravel' or the 'Empress Gravel'.[30–32] Klevberg also found an *in situ* outcrop of Saskatchewan Gravel along the Marias River of north-west Montana east of the divide. There are also outcrops of quartzite boulders in the Bears Paw Mountains of north-central Montana.[33] This material is a pre-glacial gravel capping bedrock and is often covered with diamict interpreted as glacial till. We have found that this diamict contains a fair proportion of reworked quartzite in practically all locations (figure 5). The quartzite, either from Cypflax or the Saskatchewan Gravel, is sometimes weathered and sometimes not in the diamict, indicating only a little glacial destruction. Thus, the Laurentide Ice Sheet during the Ice Age failed to erode the *in situ* Saskatchewan Gravel in some places and also failed to significantly weather quartzite clasts in the diamict, indicating very little erosive work by this ice sheet. This provides evidence that the ice sheet was thin and existed for only a short time.[28]

There are gravels, similar to the Flaxville gravel, exposed in extreme north-east Montana (called the Crane Creek gravel) and around Williston, North Dakota (called the Cartwright gravel).[34] Gravel identical to the Flaxville Gravel occurs in north-west North Dakota at and near the crest of the so-called Altamount terminal moraine.[35,36] Cypflax-like gravel also has been reported by Alden 230 km east of the north-east corner of Montana along the 49th parallel.[37]

It is interesting that all this quartzite gravel is identical. The quartzite in the Flaxville Gravel is identical to that on the Cypress Hills, although the Flaxville Gravel is dated by fossils from 1 million to 10 million years while the Cypress Hills Formation is dated as 15 million to 45 million years old. The Saskatchewan Gravel and those around Williston, North Dakota, are also identical to Cypflax Gravels.[38] These gravels are dated anywhere from Eocene to Pleistocene by index fossils. We see this as strong evidence against the Cenozoic mammal fossil-dating scheme.[39]

The combined Cypress Hills-Flaxville planation surfaces extend approximately 500 km from west to east. This implies almost 800 km transport for the quartzite to the eastern Flaxville plateau. If we include the isolated gravel locations in North Dakota, Cypflax Gravels have been transported at least 1,000 km from their nearest source area!

Non-Cypflax gravels[40]

There is a variety of surficial gravels on planation surfaces of the plains and locally on hills over Montana east of the continental divide. These gravels are south of the location of the Cypflax gravel and range from east of Glacier National Park south-east into south-eastern Montana. Much of the gravel is quartzite that is less metamorphosed than Cypflax and can be generally traced to the Rocky Mountains. Other lithologies from local mountain ranges are also found on planation surfaces. This latter gravel can be round to subangular and small to large in size.

Just east of Waterton Lakes and Glacier National Parks, matrix-supported gravels are found on erosion surfaces that form foothills (figure 15). Called the Kennedy Drift, these gravels are up to 80 m thick with lithologies similar to *in situ*

Figure 20. *Two distinct types of conglomerates about 15 km east of Lima, south-west Montana. The Red Butte conglomerate forms the side of the mountain, while the mounds in the foreground are quartzite gravel filling up the valley.*

Figure 21. *Quartzite boulders from near locality in figure 20. Madison Wolfe, three-year-old granddaughter of lead author, for scale.*

Figure 22. *Sphinx Mountain, one of the highest mountains in the Madison Range, south-west Montana. Notice the horizontal bedding.*

outcrops in the parks to the west. Uniformitarian geologists considered the gravels to be deposits made up of a number of glacials separated by interglacials and have dated them to around 2.5 Ma. The interglacial deductions are based mainly on so-called paleosols*. We have analyzed this gravel and found very poor evidence that it is glaciogenic,[41] and we believe that the deduction that these 'paleosols' separate interglacials from glacials is unsupported by the evidence.[42] About the only evidence for glaciation is striated* rocks, which can be formed by several different processes besides glaciation, such as landslides and other sediment gravity flows.[43] There are a number of reasons why the deposit is likely a debris flow that moved east off Glacier and Waterton Lakes National Parks.[41] The gravel becomes more rounded further to the east and by the time it is found north of Cut Bank, just south of the Del Bonita border station, it is well rounded and caps Alden's Number 2 Bench (figures 16 and 17).

The Fairfield Bench has already been mentioned. There are other gravel-capped benches that comprise Benches 1 and 2 north of the Fairfield Bench. The gravel, much of it quartzite, capping these benches can be traced to local lithologies in the Rocky Mountains around 50 km to the west.

Several planation surfaces mark the topography of the Judith Basin in central Montana (figure 18). Most of the gravel capping these surfaces is local to the surrounding mountain ranges.

Quartzite gravels are found on top of the Sheep Mountains west of Glendive in eastern Montana about 400 m above the Yellowstone River.[44] This gravel, called the Rimroad Gravel by Howard,[34] is fairly extensive on the hills north-west of the lower Yellowstone River and on a lower bench about 200 m above the river. Oard has also found quartzite lag gravel, some clasts that were iron stained and with percussion marks, along Highway 200S about 8 km west of Glendive.

Quartzites are found in various locations elsewhere in southern Montana.[9] Klevberg has observed high-grade quartzite cobbles and boulders with percussion marks in isolated deposits atop erosional remnants south of Billings, Montana.

South-west Montana and adjacent Idaho

Quartzites are found at many locations in the northern Basin and Range Physiographic Province (figure 19). This province is an area of crustal extension made up of horsts and grabens that have created high mountains and deep valleys or basins that are filled partially with 'valley fill' lithologies. The quartzites often are found at the surface, except where they fill paleovalleys. They are also found at the tops of some mountain ranges.

There are generally two distinct types of gravel or conglomerate in south-west Montana and adjacent Idaho. One type is a limestone cobble- and boulder-conglomerate, or breccia, and the second type is predominantly well-rounded quartzite.[45–48] The limestone conglomerate contains a minor proportion of other local lithologies.

These deposits have been given many local names, such as the Beaverhead Conglomerate, Frontier Formation, Black Butte Gravel, Divide Quartzite Conglomerate, Lima Conglomerate, Red Butte Conglomerate and Kidd Quartzite, but have been generally lumped into the Beaverhead Formation.[49] The Beaverhead Formation was raised to group status in 1985[50] and represents syntectonic conglomerate formation during mountain uplift plus the far-travelled quartzite cobble and boulder component from at least 80 km away to the west and north-west.[46] Limestone and quartzite are not usually mixed, except in the Red Butte conglomerate (which is the main limestone unit, but includes some quartzite).[51]

The limestone conglomerates are derived from the local 'Paleozoic' formations in south-west Montana and adjacent Idaho. They are red coloured because the limestone conglomerate often contains iron oxide in the matrix. The processes that eroded and deposited this conglomerate mostly occurred before the exotic quartzites from the west were transported into the area. For instance, on the top of the Gravelly Range, limestone conglomerate underlies quartzite gravel. Oard has observed the Red Butte conglomerate east of Lima that formed the sides of the mountains, while the quartzite was located in the bottom of the valley (figure 20). The clasts in the quartzite are usually large with percussion marks (figure 21).

The limestone conglomerate is of interest because it sometimes forms entire mountains. More than 1,000 vertical metres of mostly limestone conglomerate forms Sphinx Mountain (3,442 m ASL) on top of the Madison Range (figure 22).[52] There are gravel crossbeds up to 100 m thick on the north-east sided of the Sphinx,[53] indicating rapid, catastrophic deposition. Paleocurrent directions are generally toward the north-east,[52] indicating the material was transported *across the current deep Madison Valley to the west* before that valley formed.

Other mountains of limestone conglomerate are the Red Conglomerate Peaks and Knob Mountain, along the Montana-Idaho border south of Lima, Montana (figures 23 and 24).[54] One of the highest peaks in the Snowcrest Range, north-east of Lima, is Antone Peak, which is capped by over 1,600 m of limestone conglomerate.[55] Mann describes a limestone conglomerate that occurs in widely scattered outcrops on the crest of the Gravelly Range.[56,57] The limestone clasts range up to 1 metre in diameter and vary from rounded to subangular. Similar conglomerates outcrop in the Centennial region south-west of the Gravelly Range where the conglomerates are up to 1,000 m thick.[58]

These conglomeratic mountains and the scattered locations of limestone conglomerate at lower elevations likely represent erosional remnants of a vast blanket of limestone conglomerate from local sources. The deposition of a thick sheet of limestone conglomerate with the transport of clasts up to 6 m long and the subsequent erosion of much of this conglomerate during tectonic uplift and sinking

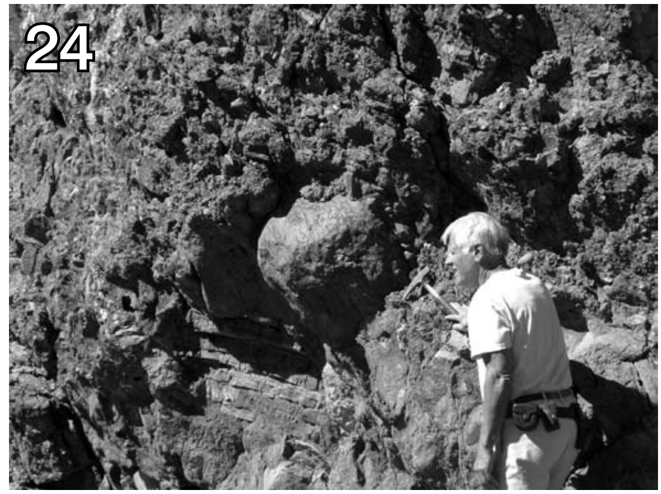

Figure 23. *Red Conglomerate Peaks along the Montana-Idaho border west of Monida Pass. Notice the south-westerly dipping beds of red-coloured limestone conglomerate. Brent Carter, creationist geologist from Boise, Idaho, in foreground.* ***24.*** *Close-up of conglomerate in the Red Conglomerate Peaks. Notice that some clasts are rounded and some angular. Brent Carter provides the scale.* ***25.*** *Quartzite boulders from the Johnson Creek Valley, north-west Tendoy Mountains, south-west Montana.* ***26.*** *Large matrix-supported quartzites on top of the Gravelly Range, south-west Montana.* ***27.*** *Well-rounded quartzite boulder about 0.6 m in diameter from on top of the Gravelly Range, south-west Montana.*

strongly indicates catastrophic action.

The quartzite gravels are usually found in the valleys (figure 25), for instance, in a small valley north-east of Ennis, Montana,[59] and in many locations from around Lima, Montana, and west to north-west to Salmon, Idaho.[60] There are also a few outcrops of well-rounded quartzite boulders on the tops of the mountains, such as the Gravelly Range above 3,000 m ASL in south-west Montana.[61,62] The clasts are well rounded and up to almost a metre in diameter on top of the Gravelly Range (figures 26 and 27). This deposit is matrix supported, and a few of the clasts are striated and faceted. It also lies on a striated bedrock pavement with chattermarks*. Because of these characteristics, the quartzite boulders on top of the Gravelly Range were once considered the deposit of an Eocene glacier, but this has since been rejected by uniformitarian geologists because the Eocene is supposed to be a time of great planetary warmth.[63]

Both the limestone and quartzite clasts can be quite large and in very thick deposits. Boulders up to 6 m long are found in McKnight Canyon north-west of Lima[64] and south-east of Lima near the continental divide.[65] Conglomerate in McKnight Canyon is around 2,900 m thick.[66] The Divide quartzite conglomerate in Idaho south of Lima is estimated to be up to 4,750 m thick.[67] We were unable to document this thickness and presume that the depth was determined by geophysical methods. A few of the quartzite clasts in the Divide Quartzite were almost a metre long with percussion marks and pressure solution marks.

Quartzites in north-western Wyoming

The quartzites of south-west Montana and adjacent Idaho extend eastward into Wyoming in a semi-continuous belt. We found scattered surficial quartzites from near Interstate 15 in Idaho, just south of Monida Pass on the Idaho/Montana border, eastward to the northern Teton Mountains. These quartzites seem to have mostly formed a lag deposit on the surface or were reworked by local mountain glaciation.

The north-western Teton Mountains contain *in situ* quartzite cobbles and boulders up to 635 m thick.[68] The largest quartzite boulder observed in this area is 138 x 122 x 75 cm located 3 km west of Survey Peak. Several remnants of rounded quartzites extend south along the present northern *crest* of the Teton Mountains.[69] Well-rounded quartzites have been found *on top* of Red Mountain in the northern Tetons, about 3,200 m high![69,70] Red Mountain and Mount Moran (3,829 m ASL) represent remnants of a flat-topped erosion surface in the northern Teton Mountains.[71] The quartzites on top of Red Mountain were up to 50 cm long (figures 28 and 29). They had percussion marks (figure 30), pressure solution marks (figure 31), and were sometimes iron stained (figure 3).

Quartzite is extensive in alluvial and glacial material in the low area from around Jackson Lake south to the city of Jackson, Wyoming.[72] This material has been reworked from elsewhere.

The most amazing quartzite gravel deposits are located east and north-east of Jackson, where thick deposits of quartzites make up 90% of the Harebell and Pinyon conglomerates.[73,74] The Harebell Formation is believed to be stratigraphically lower than the Pinyon conglomerate, with the formations extending north into south-central Yellowstone Park to Mount Sheridan. The quartzites in these two formations are identical to each other and to the Divide quartzite in Idaho. The estimated volume of the Harebell and Pinyon conglomerates is 300 km^3 with a maximum thickness of about 3,300 m, making up whole mountains. Gold occurs in the finer-grained material between the quartzites.

A very assessable exposure of the conglomerate occurs 17 to 23 km east of Moran Junction, north of Jackson, toward Togwotee Pass (figure 32). The quartzites are polished with percussion marks, typical of quartzites in most areas. Many of the quartzites are also dimpled with pressure solution marks and are fractured, indicating tremendous pressures during burial. The fact that we can find quartzites with pressure solution marks and fractures in north-west Wyoming and west into Idaho indicates that a significant amount of material has been eroded from above these surficial conglomerate outcrops. This lends credence to Love's estimate that the quartzite boulders represent erosional remnants of a volume that was once about 2,500 km^3![74]

There are other outcrops of quartzite in north-western Wyoming. The Pass Peak Conglomerate is up to 1,060 m thick in the Hoback Basin, about 30 km south of the most southern outcrop of the Pinyon conglomerate.[75,76] This conglomerate is very similar to the Pinyon Conglomerate in that the clasts are 90 to 100% quartzite, and the clasts are well-rounded, polished, fractured, contain gold in the matrix and are marked with percussion and pressure solution marks. The conglomerate is cross-bedded in places,[75] just like the quartzite conglomerate that outcrops in the western Bighorn Basin. Dorr, Spearing and Steidtmann[77] claim that the conglomerate was reworked from the Pinyon conglomerate, but Love disagrees because the clasts are too large (up to 40 cm along the long axis) and are unbroken contrary to what is expected since the Pinyon quartzite is well fractured.

There is quartzite gravel within diamict, presumably glacially derived, that occurs on the surface of the northern Green River Basin around Pinedale. These quartzites likely were derived from the north, so were included in figure 5. There are also isolated outcrops of quartzite gravel in the western and southern Green River Basin and in Fossil Basin of south-west Wyoming. However, these will not be included in this survey because there are also possible sources of quartzites in the mountains of south-east Idaho and adjacent south-west Wyoming, as well as the Uinta Mountains of north-east Utah.

Rounded quartzite gravel outcrops sporadically in the western Bighorn Basin (figure 33) and the north-west portion of the Wind River Basin.[78,79] The quartzite boulders are up to 40 cm long and a small amount of gold occurs in the fines. Lindsey claims[78] that these quartzites are different from the Harebell and Pinyon quartzites because there are more lithologies and the quartzites are more subrounded. Love believes these quartzites are 'partial-lateral equivalents'.[79] However, Kraus states that the quartzite gravels are lithologically similar to the quartzite conglomerates in north-west Wyoming, south-west Montana and adjacent Idaho.[80] The western Bighorn Basin quartzites have fascinating large-scale cobble and boulder cross beds over 5 m thick that were deposited as planar cross beds. Kraus is surprised at the thickness and lateral extent of these planar cross beds:

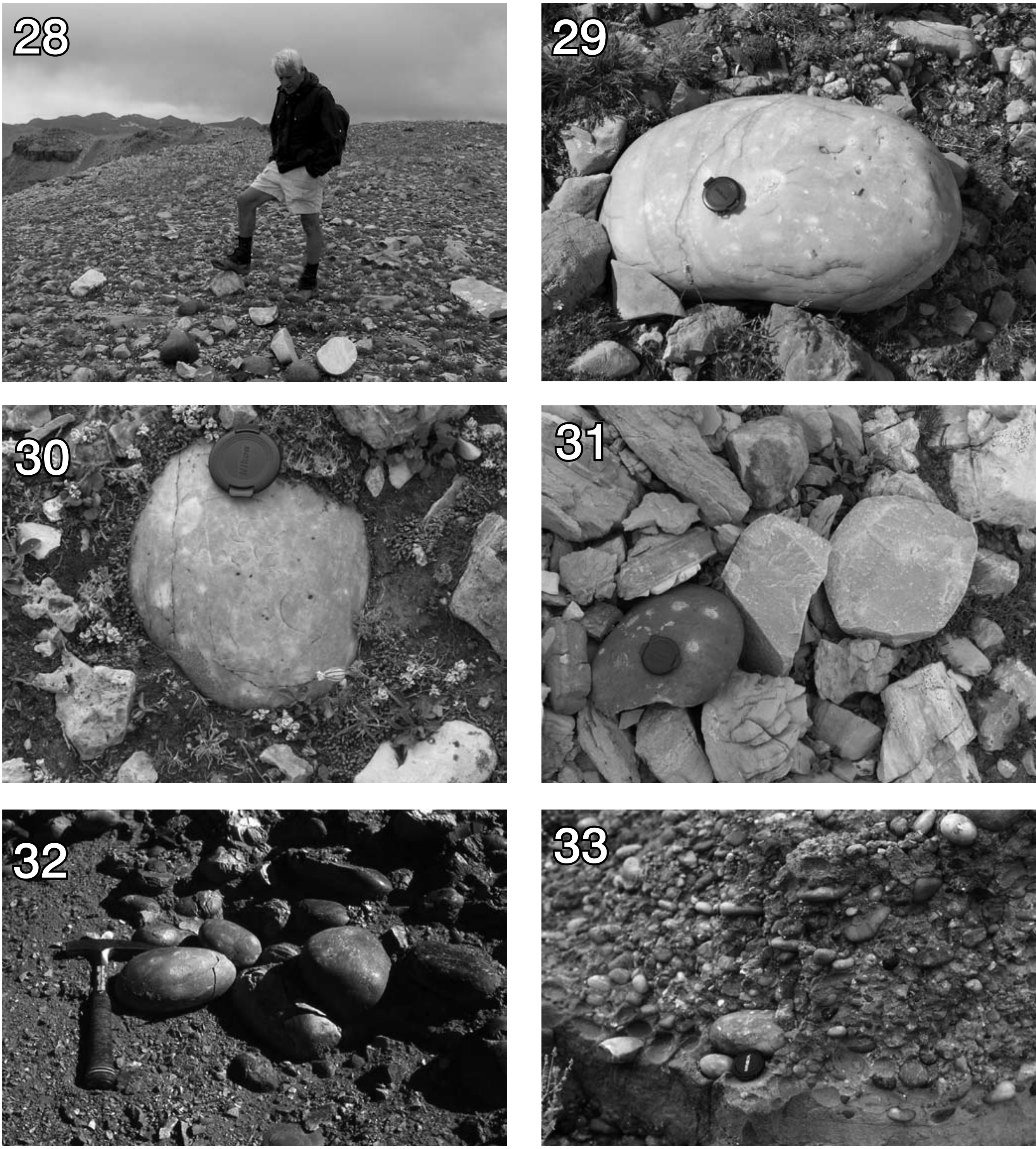

Figure 28.** Quartzites from top of Red Mountains, northern Teton Mountains, mixed with angular limestone clasts. Split quartzites probably due to frost action along pre-existing fractures. Brent Carter provides the scale.* ***29. *Largest quartzite boulder, about 50 cm long, from on top of Red Mountain. Faint pressure solution mark just to the right of camera lens cap.* ***30.*** *Percussion marks on quartzite from on top of Red Mountains.* ***31.*** *Pressure solution marks on an iron-stained quartzite from on top of Red Mountain. Note texture of the typical quartzite to the right.* ***32.*** *Outcrop of quartzite gravel about 20 km east of Moran Junction. Note that the quartzites have pressure solution marks and percussion marks, and are polished and fractured.* ***33.*** *Quartzite gravel in south-west Bighorn Basin along Highway 431, 5 km east of Highway 120, north-central Wyoming.*

Figure 34. *Quartzite gravel on a pediment east of Sheep Mountain water gap, north-eastern Bighorn Basin, north-central Wyoming.*

> 'Planar cross-sets are remarkably extensive in directions both perpendicular and parallel to paleoflow. A single set … can be traced approximately 450 m in a direction perpendicular to the general paleoflow for the exposure … . The abundance and magnitude of planar cross-sets in the *Gp* facies assemblage [stratified gravel] is unusual, especially in comparison with deposits described from modern gravel streams.'[81]

Quartzite boulders are found among andesite conglomerate on top of Tatman Mountain, over 500 m above the valley, in the central Bighorn Basin.[82] Kraus states that there are no quartzites in the eastern Bighorn Basin.[83] She probably means there are no *in situ* quartzites. However, Oard has found quartzites at quite a few locations on pediments, terraces and bluffs in the eastern Bighorn Basin (figure 34). It is likely that some of this gravel, especially on river terraces, has been reworked by the river. The locations in the eastern Bighorn Basin represent a further eastward transport of about 50 km across the Bighorn Basin. The total distance of travel from the west for the quartzite gravels in the eastern Bighorn Basin is 350 to 600 km!

Summary

Three broad areas of surficial, quartzite gravel, which have been transported east of their apparent source areas in the northern Rocky Mountains have been investigated.

The Cypflax quartzites spread more than 1,000 km across northern Montana, adjacent Alberta and Saskatchewan, and into north-western North Dakota. They are commonly iron stained with percussion marks and cap the Cypress Hills and Flaxville planation surfaces that are now plateaus high above the surrounding rivers.

South of the area of Cypflax, quartzites are found on the Montana plains extending as far east as Glendive in eastern Montana. The clasts include many lithologies from local mountain ranges as well as Rocky Mountain source quartzites.

In south-west Montana, north-west Wyoming and adjacent Idaho quartzite and limestone cobbles and boulders from the Rocky Mountains have been identified. The quartzites in this area are up to 1 metre in diameter and are not only iron-stained with percussion marks, but also commonly dimpled with pressure solution marks and cut by fractures, indicating burial under significant pressure. These quartzites are found at numerous locations from valley floors to mountain tops, including the northern Teton Mountains. They have been spread as far east as the eastern Bighorn Basin, 350 to 600 km from their source.

In a subsequent paper, we will document the spread of quartzite gravels west from their source, clear to the Pacific Ocean and in our final paper, we will delve into the uniformitarian hypotheses that attempt to account for all this long-distance transported quartzite. We conclude that the spread of quartzites is strong evidence for the Recessional Stage of the Genesis Flood in the north-west United States and adjacent Canada. The quartzites also provide additional insight into the phenomenal earth processes in operation at the time of Noah.

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Glossary

Argillite: slightly metamorphosed siltstone or shale.
ASL: above mean sea level.
Chattermarks: small, curved cracks commonly found in nested arrangements.
Clast-supported: individual gravel clasts touch each other, rather than being separated by a matrix of finer material.
Diamict: unconsolidated sediment made up of rocks of various sizes within a finer-grained matrix. Glaciation and landslides are two processes that can cause diamict. When consolidated it is called diamictite.
Imbricated: the flat surfaces of gravels, pebbles or grains are stacked with their flat surfaces dipping upstream.
Massive: homogeneous structure or texture.
Paleosols: old soil horizons usually buried by more recent geological layers.
Patina: surficial coating due to weathering, commonly comprised of iron oxide.
Percussion marks: circular to semicircular (conchoidal) cracks on the surface of rocks due to impacts.
Poorly-sorted: a wide-mixture of sizes.
Pressure solution marks: small circular cavities caused by the pressure of one clast against another, melting the rock at the contacts. Such features are caused by the pressure or weight from rocks or sediments above (see figure 28).
Striated: approximately parallel groves and scratches cut in a rock.

Subjacent: approximately adjacent in a geological context.

Unlithifieid: lithification is the conversion of unconsolidated sediments into a solid rock.

*Vitreous***:** having a glassy texture.

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