Geometry, Distribution, and Provenance of Tectogenic Conglomerates Along the Southern Margin of the Wind River Range, Wyoming

J. R. Steidtmann
University of Wyoming
Laramie, Wyoming

L. T. Middleton
Northern Arizona University
Flagstaff, Arizona

R. J. Bottjer[1]
K. E. Jackson[2]
L. C. McGee[3]
E. H. Southwell
University of Wyoming
Laramie, Wyoming

S. Lieblang[4]
Northern Arizona University
Flagstaff, Arizona

Surface and subsurface studies of the tectogenic conglomerates along the southern margin of the Wind River Range show that they are of three general types with regard to size, geometry, and depositional environment and that each of these types can be related to a specific structural setting. The Fort Union Formation (Paleocene) and the main body of the Wasatch Formation (early Eocene) make up a large clastic apron and were generated by uplift of the range as a whole along the Wind River fault zone. The South Pass Formation (late Oligocene–early Miocene), conglomerate in the White River Formation (Oligocene), and the recently identified Leckie Beds (post–South Pass) are each intramontane alluvial deposits that indicate faulting in the core of the range. Fault scarp clastic wedges in the Cathedral Bluffs Tongue of the Wasatch Formation (early Eocene) and the newly recognized Circle Bar beds (Miocene) document up-to-the-north motion along the Continental fault during Eocene time and later postcompressional collapse (down-to-the-north) in Pliocene time.

Conclusions from this study suggest that a steep tear fault may have uncoupled the Wind River Range from basins to the south as it was thrust toward the southwest. Furthermore, there may have been significant uplift in the core of the range after the main motion on the Wind River fault, and therefore, Laramide deformation may have lasted long after early Eocene time.

INTRODUCTION

The Wind River Range is the largest uplift in the Wyoming foreland province, exposing Precambrian crystalline rocks along a core 125 mi (200 km) long and 25 mi (40 km) wide in west-central Wyoming (Figure 1). It was uplifted by motion on the Wind River fault which shortened the crust by at least 13 mi (20 km) (Brewer et al., 1980) and vertically offset the crystalline basement by at least 7 mi (11 km). During and after uplift in late Cretaceous and Tertiary time, the Paleozoic and Mesozoic sedimentary cover and the crystalline core of this range were eroded and large volumes of sediment were shed into adjacent basins. Thus, the history of the uplift and subsequent collapse of the range are recorded in these syntectonic and posttectonic sedimentary rocks, and specific structural and compositional aspects of the uplift are reflected in sediment composition, texture, geometry, and distribution.

Presumably, a similar relationship between uplifted source rock and derived sediments existed for most of the ranges

[1]Present Address: Amoco Production Company, Denver, CO.
[2]Present Address: Tenneco Oil Company, Lafayette, LA.
[3]Present Address: U.S. Geological Survey, Denver, CO.
[4]Present Address: Union Oil Company of California, Los Angeles, CA.

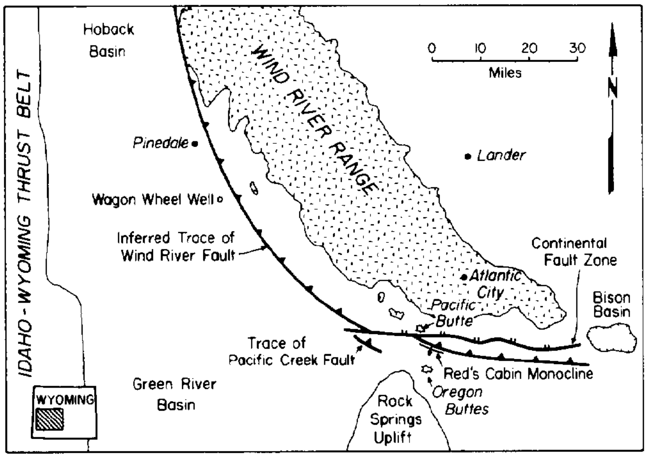

Figure 1—Index map showing location of the study area and the physiographic and geologic features discussed in the text.

throughout the Rocky Mountain foreland, but along the south end of the Wind River Range, postcompressional collapse has been sufficient to lower these sediments and thus preserve them from erosion. In this area, a relatively complete record of latest Cretaceous and Tertiary mountain flank sediments, some possibly as young as Pliocene, are preserved.

This paper reports preliminary results of our studies to determine the distribution and stratigraphic relationships among the conglomeratic facies of these deposits and to infer from their composition, texture, and sedimentary structures their relationship to the uplift and collapse of the range. Our interpretations are, to a large degree, based on the assumption that large accumulations of coarse clastics require steep gradients and topographic relief, which in turn may be related to faulting. Data for our study come from our own surface and subsurface observations as well as the published works of others.

Our findings indicate that the main conglomerate units are of three general types with regard to size, geometry, and depositional environment and, furthermore, that each of these types can be related to a specific structural setting. Large (subregional) basin margin aprons of proximal and distal alluvial fan deposits flank the entire west and south sides of the range (Berg, 1963) and are apparently related to the main uplift of the range by movement on the Wind River fault. Within the range, more separate and distinct proximal alluvial deposits were generated by subsequent faulting that uplifted the Precambrian core over much of the length of the range. Finally, very local, extremely coarse prisms of proximal alluvial fan sediments were deposited immediately adjacent to steeply dipping tear faults that were later the sites of postcompressional collapse of the range.

Stratigraphic Setting

Sedimentary rocks associated with uplift and subsequent collapse of the Wind River Mountains range in age from latest Cretaceous (Lance) through Tertiary (Figure 2), but only those that are Eocene and younger are well exposed at the surface. The stratigraphic relationships and zircon fission-track ages for several of these units are discussed by Steidtmann and Middleton (1986).

Those conglomerate units that we feel are a direct response to motion on faults along or within the southern end of the Wind River Range include the Fort Union Formation (Paleocene), main body of the Wasatch Formation (early Eocene), Cathedral Bluffs Tongue of the Wasatch Formation (early Eocene), South Pass Formation (late Oligocene–early Miocene), conglomerate beds in the White River Formation (Oligocene), the Circle Bar beds (Miocene), and the Leckie beds (post–South Pass). The distribution of these units and general paleocurrent directions for each are summarized in Figure 3.

SUBREGIONAL CLASTIC APRON

Introduction

The Fort Union (Paleocene) and main body of the Wasatch (early Eocene) in this area make up the large clastic apron that flanks the Wind River Range along its western and southern margins. Most of these sediments are of alluvial plain or distal alluvial fan origin. In general, proximal facies of these deposits are not observable because they have been overrun by the Wind River fault and few cores record them at depth. Thus, neither the structural relationships between these deposits and the range itself, nor their coarseness and its implications concerning stream gradients, are known.

Fort Union Formation

The Fort Union is present only in the subsurface in the immediate area. To the south it is exposed in the Rock Springs uplift (Figure 1) where it is as much as 1800 ft (575 m) thick and composed mainly of interbedded sandstone, conglomerate, mudstone, and coal (Winterfeld, 1979). To the east it is exposed in the Bison basin (Figure 1) where it is about 900 ft (275 m) thick. Here it consists of a sequence of thin, lenticular conglomerate beds and medium- to coarse-grained planar- and cross-bedded sandstone enveloped in carbonaceous overbank siltstone and claystone (Southwell, in prep.). These overbank deposits constitute more than 90% of the Fort Union in the Bison basin and, in places, show pedogenic differentiation and both floral and faunal bioturbation. Although the great amount of overbank facies suggests a meandering river environment, the association of large-scale trough cross-stratification, planar-bedding, and scour-and-fill structures in the sandstone and conglomerate indicate mid-channel bars and bedforms of a braided stream (Figure 4). This association of overbank and braided channel deposition is typical of an anastomosing stream as described by Smith and Putnam (1980).

The conglomerate consists of subangular to well-rounded clasts 0.25–4 in. (0.6–10 cm) in diameter. Clasts are composed of gray, black, green, and banded chert and siliceous sandstone and shale fragments. For the most part, the chert appears to be derived from the Madison Limestone (Mississippian) and Phosphoria Formation (Permian); the sandstone fragments from the Tensleep Sandstone (Pennsylvanian), Nugget Sandstone (Jurassic), and Cloverly Formation (Cretaceous); and the shale clasts from the Mowry Shale (Cretaceous). These channel-fill sequences average approximately 8 ft (2.5 m) in thickness and 160 ft (48 m) in lateral extent. Cross-bedding indicates a sediment

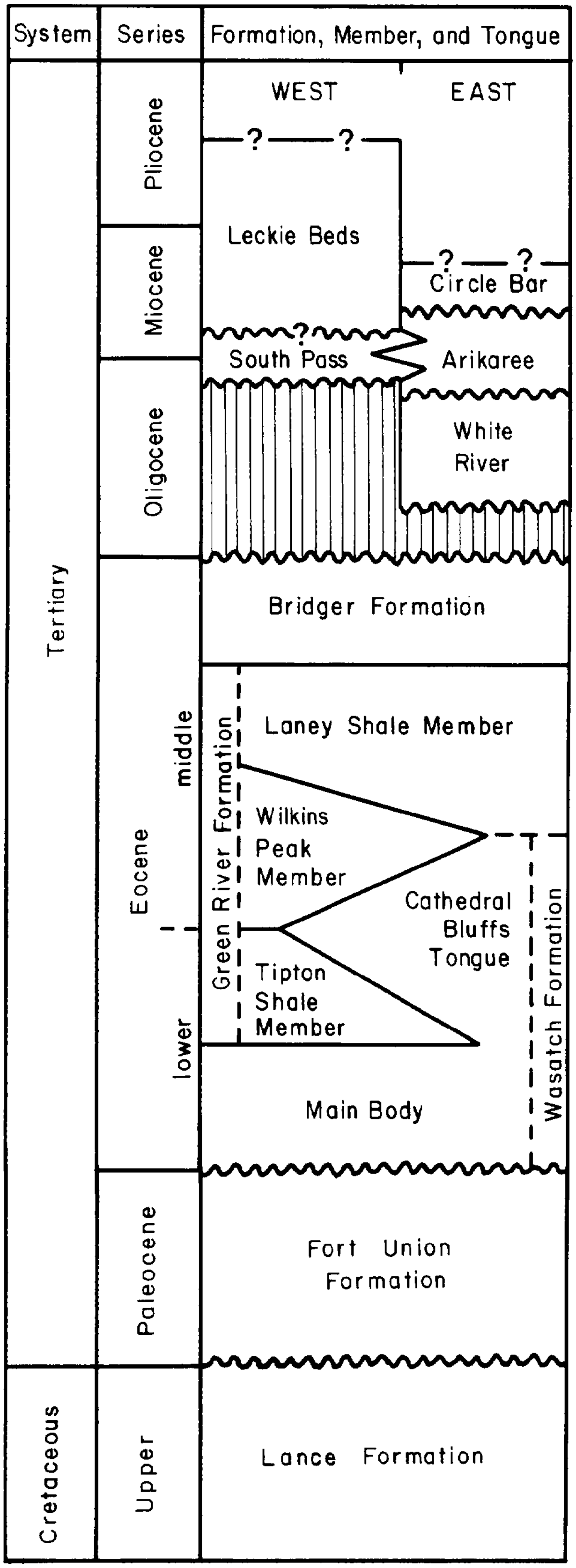

Figure 2—Composite stratigraphic section showing the relationships among Tertiary units exposed along the south flank of the Wind River Range. Adapted in part from Zeller and Stephens (1969).

source to the northwest (Figure 3). The association of mechanically more labile shale clasts with the ultradurable chert clasts suggests a short transport history and therefore a nearby source (Abbott and Peterson, 1978).

Along the south and west flanks of the range our information about the Fort Union comes entirely from the subsurface. Our examination of cores from the Wagon Wheel well (Figure 1) indicates that about 1200 ft (360 m) of sediment, palynologically dated as Paleocene (Law, 1981), consists mainly of K-feldspar granules floating in a silt matrix and suggests that proximal fan deposition (mudflow?) during the Paleocene occurred at least 12 mi (20 km) west of the buried trace of the Wind River fault. Furthermore, these deposits indicate that, at least in this area, erosion had reached the crystalline core by early Paleocene time. Whether or not these beds should be called Fort Union is debatable. Law (1981) referred to them as the "unnamed unit" and indicated that this unit is conformably overlain by the Fort Union in the deeper part of the basin. Near the perimeter of the basin this contact is unconformable. This unnamed unit is truncated and does not appear at the surface.

In his discussion of Laramide sediments along the Wind River fault, Berg (1963) described a Paleocene "basinal facies" composed of nonmarine shale, coal, siltstone, and sandstone that he designated as the Hoback Formation because of its similarity to this unit exposed at the surface in the Hoback basin 80 mi (130 km) to the northwest. These are most likely the same sedimentary rocks identified as Fort Union by Law (1981).

Unfortunately, Law's (1981) correlation does not differentiate the Fort Union from the overlying early Eocene Wasatch Formation, and it is therefore difficult to determine the respective thicknesses. Furthermore, because of the complex lateral and vertical facies changes between the two units, it is likely that their thicknesses change rapidly from place to place. Estimates from Berg's (1963, his figure 8) schematic diagram indicate that the Fort Union may be as thick as 7000 ft (2100 m) and the Wasatch as much as 6000 ft (1800 m). The log from the Wagon Wheel well (Martin and Shaughnessy, 1969) shows thicknesses of about 3300 ft (1000 m) for the Fort Union and 7000 ft (2100 m) for the Wasatch. Zeller and Stephens (1969) stated that the average thickness of the Wasatch in wells drilled south of Oregon Buttes (Figure 1) is just over 3000 ft (900 m). This rather wide range of thicknesses for the Fort Union and Wasatch is probably a function of the range of true thicknesses, errors in estimates from the subsurface because of difficulties in picking Tertiary tops, and structural complexities.

Local thickness variations of the Fort Union and the underlying Lance Formation may indicate time of motion on the Pacific Creek fault (Figure 1). Seismic sections indicate that units identified as Lance and Fort Union thin locally. MacLeod (1981) interpreted this to indicate control of local depositional patterns by motion on the Pacific Creek fault in latest Cretaceous and Paleocene time.

Main Body of the Wasatch Formation

The upper part of the main body of the Wasatch Formation is exposed in the southwestern part of the area (Figure 3), but here too it is likely that most of the proximal

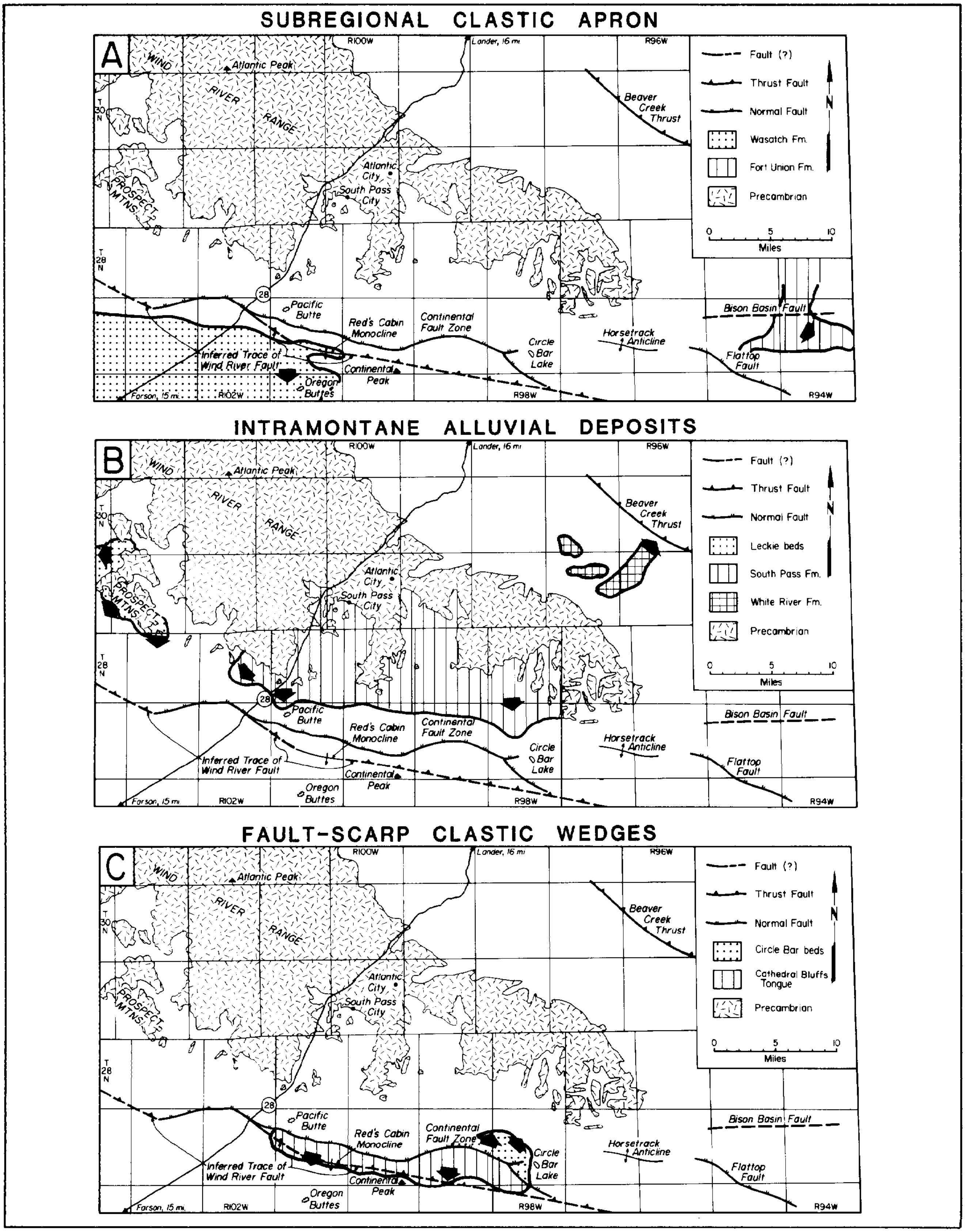

Figure 3—Distribution and general paleocurrent directions of tectogenic conglomerate units along the south flank of the Wind River Range. A. Subregional clastic apron deposits (Fort Union and main body of the Wasatch). B. Intramontane alluvial deposits (South Pass, White River, and Leckie). C. Fault scarp clastic wedges (Cathedral Bluffs and Circle Bar).

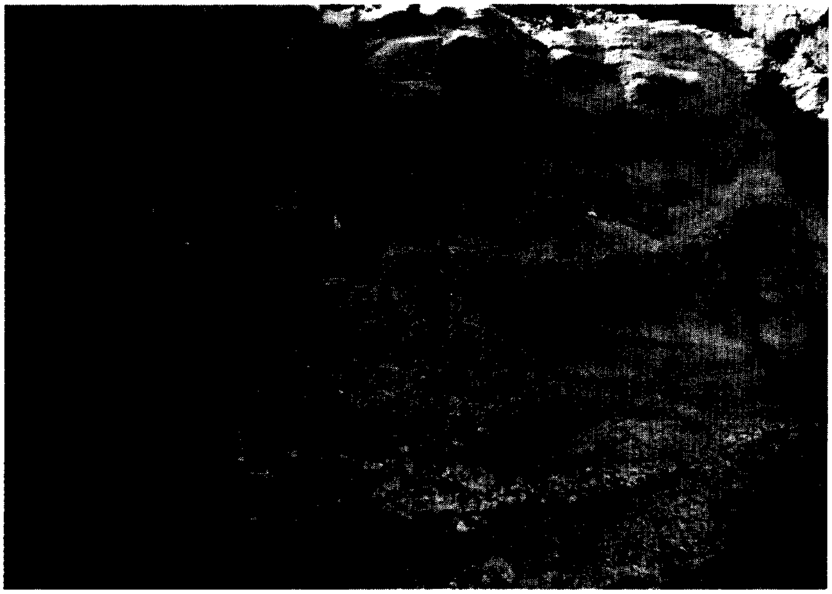

Figure 4—Sandstone and conglomerate facies of the Fort Union Formation in the Bison basin. Outcrop shows stacks of stringerlike fills of trough cross-bedded sandstone and conglomerate composed of angular clasts. Hammer shows scale.

deposits have been overrun by the Wind River fault and are not available to direct observation. The main body consists of variegated mudstone, sandstone, and feldspathic pebble conglomerate. These beds can be distinguished from the overlying, lithologically identical Cathedral Bluffs Tongue of the Wasatch Formation only where the Tipton Tongue of the Green River Formation separates the two. Near Pacific Butte (Figure 1) the upper 180 ft (50 m) of the main body is exposed in the core of Red's Cabin monocline (McGee, 1983). The upper part of the main body of the Wasatch is composed of beds of red and gray conglomerate 2–4 ft (0.6–1.2 m) thick that fine upward into variegated drab, maroon, tan, and greenish-blue sandy, arkosic siltstone, mudstone, and claystone. Here, only about 7% of the main body consists of conglomerate beds that are generally only moderately well sorted and in some places contain up to 40% silt and sand matrix. Clasts are subrounded, as much as 3 in. (8 cm) in diameter, and include schist, vein quartz, chert, and gneiss. Crude horizontal or very low-angle cross-bedding is outlined by pebble imbrication, which, along with rare high-angle cross-bedding, indicates a southerly transport direction (Figure 3).

The distance from probable source and the sedimentary texture and structures of the main body indicate deposition on an alluvial braid plain. The low-angle and horizontal stratification represents high velocity flow in braided channels with deposition occurring on longitudinal bars. The fining-upward sequences from conglomerate to sandstone attest to waning flow following major flood events. The lateral impersistence of the coarse facies is consistent with sheet flooding both within and proximal to incised braided channels on the medial to distal parts of an alluvial fan system (Bluck, 1967; Steel, 1974). Presence of matrix-supported beds indicates that this depositional style was periodically interrupted by debris flows. Larsen and Steel (1978) described a similar conglomerate and explain the abundance of matrix by repeated inundation of fan slopes by water and fine-grained sediment in a tectonically unstable area resulting in the addition of fines to previously deposited coarse clastics.

INTRAMONTANE ALLUVIAL DEPOSITS

Introduction

The alluvial deposits that we relate to faulting in the core of the range include the South Pass Formation (late Oligocene–early Miocene), conglomerate in the White River Formation (Oligocene), and the Leckie beds (post–South Pass).

South Pass Formation

The South Pass Formation is a granule to boulder conglomerate, 0–350 ft (0–105 m) thick exposed along the south flank of the Wind River Range (Figure 3). It overlies rocks of the Bridger Formation (middle Eocene) and locally overlies Precambrian crystalline rocks.

The conglomerate consists of pebbles, cobbles, and boulders in a matrix of coarse sand and pebbles (Bottjer, 1984). Clast composition of the South Pass is variable, reflecting both the complex source rocks of the Precambrian and sediment supply from proximal and distal sources. Presence of well-rounded and very angular grains of the same size and composition in the matrix supports the interpretation of both proximal and distal sources. Clast types include granite, diabase, basalt, gneiss, granodiorite, and epidotized and sheared crystalline rocks.

Although the conglomerate is generally matrix supported, deposition by fluvial processes is indicated by the coarseness of the matrix (sand to pebbles) and the fact that it is well stratified. Gross lenticular bedding, scour surfaces, cross-stratification, channel fills as much as 100 ft (30 m) wide, and clast imbrication all suggest deposition in braided streams with low bed relief. Shallow flows are indicated by the predominance of planar bedding (Allen, 1967), which for coarse sediments (i.e., grains more than 0.6 mm in diameter) is a stable bed configuration in both the upper and lower flow regimes (Southard, 1971). Both downstream and laterally accreting mid-channel bars are indicated by large-scale planar cross-stratification that dips both parallel and oblique to the mean flow direction. Figure 5 shows a transverse cross section of a gravelly mid-channel bar that grew by vertical aggradation and lateral accretion.

Weak distributary paleocurrent trends (Figure 3), proximity to major uplifts, and the coarseness of the deposits all indicate an alluvial fan setting adjacent to highlands within the core of the Wind River Range.

Conglomerate in the White River Formation

Conglomerate beds similar to those of the South Pass occur in the White River Formation near the southeastern terminus of the Wind River Range (Figure 3). The conglomerate and coarse sandstone beds are laterally discontinuous and enveloped in white, ashy siltstone characteristic of the White River. The conglomerate is mainly clast supported but contains rare matrix-supported beds.

In the eastern part of the deposit clasts of igneous and metamorphic rocks dominate, the most common rock types being granite, quartz monzonite, and mafic plutonic rocks. Sedimentary rock fragments dominate the clast population in the western part of the area and include sandstone from the Flathead (Cambrian), Tensleep (Pennsylvanian), and Chugwater (Triassic) formations; siltstone from the Gros Ventre Formation (Cambrian); intraformational conglomerate and limestone from the Gallatin Limestone (Cambrian); dolomite from the Bighorn Dolomite (Ordovician) and Amsden Formation (Pennsylvanian); and chert from the Phosphoria Formation (Permian).

The abundance of clast-supported conglomerate, clast imbrication, high gravel:sand ratio, poor sorting, and scoured surfaces suggests a braided stream environment (Lieblang, 1983). Laterally discontinuous conglomerates are typical of modern braided systems (Smith, 1970; Collinson, 1978), and longitudinal, diagonal, and transverse bars, similar to those in the South Pass Formation, were identified by association of sedimentary structures and unit geometries (Lieblang, 1983).

Longitudinal bars were recognized in the field by a basal deposit of massive, clast-supported conglomerate and/or horizontally stratified clast- and matrix-supported conglomerate overlying a scoured base (Figure 6). These units were apparently emplaced during major flooding events as diffuse gravel sheets (Hein and Walker, 1977). The remainder of the bar is composed of trough cross-stratified conglomerate and sandstone reflecting lower stage cut and fill during emergence. Finer grained facies representing settling during low energy stages compose the bar tops.

Although not as abundant, facies associations representing transverse bar formation and migration also occur. These consist of basal units of large-scale planar tabular cross-bedding (avalanche deposition on bar fronts) overlain by horizontally stratified beds (upper flow regime sheet flow across bar tops). Dune migration in channels is indicated by stacked sequences of trough cross-stratified sandstone and numerous cut-and-fill structures.

An eastward paleocurrent direction is indicated by the analysis of clast imbrication and is supported by a west-to-east decrease in labile clast components and clast size (Figure 3). Furthermore, there is an eastward change from proximal (longitudinal) to distal (transverse) bar types similar to that described by Smith (1970), Hein and Walker (1977), and Collinson (1978).

Leckie Beds

The deposits we here informally designate as the Leckie beds have only recently been identified as tectogenic in origin. Thus, much remains to be learned about their composition, provenance, and structural relationships. Until 1983 these coarse clastics were considered to be of glacial origin following the interpretation of Moss and Holmes (1955). Mapping described by Richmond (1983), however, shows these deposits to be discrete, bouldery alluvial fans immediately adjacent to topographic highs along the west and southwest side of the Wind River Range (Figure 3). The depositional surface and shape of these fanglomerates is preserved at several localities and according to Richmond (1983), the beds are offset by normal faults, some possibly of Quaternary age. Our field observations generally corroborate those of Richmond, but we favor the more cautious age designation of post–South Pass rather than his Miocene until more data have been collected.

FAULT SCARP CLASTIC WEDGES

Introduction

Wedges of proximal fan deposits formed along steeply dipping faults that were probably tear faults during uplift of the range and were later sites of postcompressional collapse. Those deposits along the tear faults are represented by the Cathedral Bluffs Tongue of the Wasatch Formation (early Eocene) and those along the collapse faults by the Circle Bar beds (Miocene), recently identified by Jackson (1984). Although the Cathedral Bluffs is significantly coarser than the Circle Bar, both represent extremely local deposition along fault-controlled topographic highs. Textural and compositional differences between the two units are related to the source rock.

Cathedral Bluffs Tongue of the Wasatch Formation

Where the Tipton Tongue of the Green River Formation is present, an upper unit of the Wasatch Formation, the Cathedral Bluffs Tongue, is recognized in the eastern Green River basin. It consists of arkosic siltstone, sandstone, and conglomerate generally quite similar to, although coarser than, the main body of the Wasatch (McGee, 1983). It changes thickness markedly over short distances, ranging from less than 100 ft (30 m) on the southeast end of Red's Cabin monocline to more than 700 ft (210 m) just 1 mi (~1.5 km) northwest on Pacific Butte (Figure 3).

In the vicinity of the monocline, boulder–cobble conglomerate is interbedded with variegated siltstone and

Figure 5—Transverse cross section of a gravelly mid-channel bar in the South Pass Formation. Bedding shows that the bar grew both by lateral accretion (A) and vertical aggradation (B). Lens cap shows scale.

claystone. The cobble-sized clasts are as much as 10 in. (25 cm) in diameter, consist of dark schist and gneiss with some chert and quartz, and show both isolate and contact imbrication. Boulders as large as 15 ft (4.5 m) in diameter are strewn over the surface of Pacific Butte (Figure 7), and discontinuous patches of similar sized boulders are present at several other locations immediately adjacent to the Continental fault (Figure 3). Apparently these boulders are a weathering lag reworked out of the Cathedral Bluffs, and they decrease in both size and number away from the Continental fault until none are present only 1 mi (~1.5 km) to the south.

Most of the largest clasts are composed of granite, gneiss, schist, pegmatite, and pegmatitic quartz. The relative amount of these clast types varies markedly over very short distances, indicating distinctive source rock types and transport distances short enough to inhibit mixing. Rocks of the greenschist–amphibolite metamorphic facies near Atlantic City (Figure 1) 12 mi (~20 km) to the northeast make up most of the pebble- and cobble-sized clasts, whereas the boulders are mainly pegmatite and granite derived from just north of the fault. At several locations these conglomerates contain gold that also had a nearby source (Love et al., 1978).

The decrease in maximum clast size southward from the Continental fault and the general gradation from conglomerate to sandstone and siltstone toward the south suggest deposition in a south-flowing alluvial system characterized by discrete, low-sinuosity channels such as might occur on the proximal and medial parts of alluvial fans (Figure 3). Sedimentary structures consist of low-angle to horizontal stratification, well-developed clast imbrication, and cut-and-fill sequences. These features are common on modern longitudinal bars in braided systems (Ore, 1963; Hein and Walker, 1977; Miall, 1977).

Thin beds of arkosic, conglomeratic sandstone are interbedded with the conglomerate units. These sands probably were deposited on the downstream reaches of longitudinal bars during low-flow stages (Bluck, 1979; Steel and Thompson, 1983) and also filled topographically low areas oblique to the bar axes that were scoured out during low-stage bar dissection.

The proportion of mudstone increases to the south and reflects more distal fan and upper alluvial plain sedimentation. Roehler (1969) also considered the sandstone and conglomerate in the Cathedral Bluffs to represent alluvial fan deposits that grade into mudstone and fine sandstone on an alluvial plain.

Circle Bar Beds

A previously unrecognized sequence of tuffaceous sandstone, volcanic ash, and conglomerate was informally designated the Circle Bar beds by Jackson (1984) for exposures along the north side of the Continental fault ~17 mi (27 km) southeast of Atlantic City (Figure 3). Previously, these rocks had been mapped as part of the Arikaree Formation (Oligocene–Miocene) by Denson and Pipiringos (1974) and Zeller and Stephens (1969). The Circle Bar unit varies in thickness from 260 to 400 ft (80 to 120 m) over a distance of only 2 mi (~3 km) and rests with angular unconformity on the Bridger (middle Eocene) and Arikaree (Oligocene–Miocene) formations where they have been folded along the Continental fault. There is no doubt that the Circle Bar is younger than early Miocene because it overlies and contains reworked fragments of the Arikaree Formation. Jackson (1984) assigned it an age of late Miocene or Pliocene and Steidtmann and Middleton (1986) obtained a middle Miocene zircon fission-tracks age from ash beds in this unit.

The lower part of the Circle Bar beds consists of fine-grained, gray, tuffaceous sandstone containing scattered pebbles of Precambrian crystalline rocks, broken and rounded fragments of white, silicified root casts, and boulders of sandstone from the Arikaree Formation. The Circle Bar coarsens upward and toward the southwest where lenses and continuous beds of pebble, cobble, and boulder

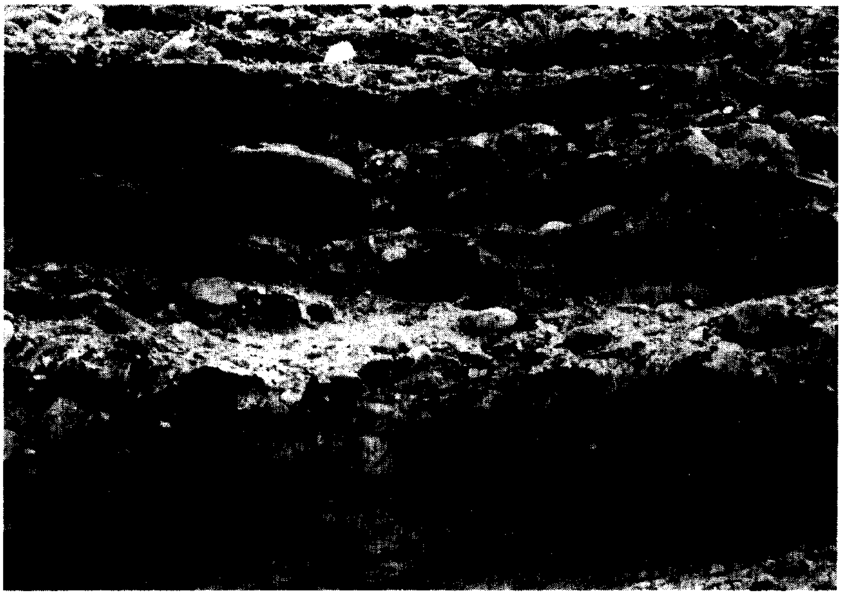

Figure 6—Cross section of longitudinal bar in conglomerate of the White River Formation. Bar consists of massive, structureless clast- and matrix-supported conglomerate (A) interbedded with finely laminated siltstone (B) scoured into massive, tuffaceous siltstone (C). Hammer shows scale.

conglomerate are interbedded with, and channeled into, cross-bedded tuffaceous sandstone. Fragments of metagraywacke and other mafic metamorphic rocks constitute most of the clasts of pebble and cobble size and were probably derived from the basal conglomerate of the adjacent Arikaree Formation where only these sizes are available. Rounded fragments of Arikaree sandstone make up most of the boulder-sized clasts, some as large as 9 ft (3 m) in diameter.

Paleocurrent directions, shown by imbrication of the tabular metamorphic clasts, indicate transport toward the north and northeast (Figure 3). These directions, along with the clast size trends and the reworked fragments of Arikaree sandstone indicate that sediments of the Circle Bar beds were shed off a high-standing southern block along the Continental fault. Deposition was restricted to the immediate vicinity of the topographic high on alluvial fans where, from time to time, ash-rich sediment accumulated in small ponds.

DISCUSSION

The schematic diagram in Figure 8 shows the general distribution of the three types of conglomeratic units and their relationships to major structural elements. Although there are other conglomerates in the Tertiary record of this area, most are thin and discontinuous and cannot be related to identifiable events associated with the structural development of the Wind River Range. The widespread, range-encircling nature of the Fort Union and main body of the Wasatch clastic apron indicates that these sediments recorded the uplift of the range as a whole. This is not to say, however, that the sedimentary record indicates that the range was uplifted as one intact block along its entire length. On the contrary, interpretations by Berg (1983) and Steidtmann et al. (1983) suggest that the Wind River fault is a zone consisting of numerous segments that may have moved independently. It is unlikely, however, that additional source area and current direction studies will have the resolution to identify separate uplifted blocks. The data are simply not available at the surface or in the scant subsurface record and subtle source area and current direction differences between individual, but coalescing, fans of various sizes would be difficult to recognize. Furthermore, much of the evidence has been overrun by syndepositional movement on the Wind River fault.

Because of the separate and distinct nature of the intramontane alluvial deposits (Figure 8), they can be used as evidence for uplift in specific areas. Analysis of the South Pass Formation indicates uplift in the core of the range that postdates main motion on the Wind River fault. This interpretation is indicated by several lines of evidence including paleocurrent indicators (Figure 3), position of the deposit on the toe of the Wind River fault, textural evidence for both distal and proximal sources, and lack of compositional control by local source rocks.

The nature of this uplift in the core is not certain but it is quite likely that it occurred along faults or fault zones that now occupy the obvious break in slope immediately west of the highest part of the range (Figure 9). Faults and fault zones similar to those envisioned for this area have been mapped northward along the range by Richmond (1945), Berg (1961, 1963), and Frost (personal communication, 1984). Couples and Stearns (1978, their figure 9) indicate a fault at this position bounding the east side of their "shattered lobe." If volume of derived sediment is an indicator of displacement along the fault, it is clear that uplift along this proposed fault was significantly less than that on the Wind River fault, probably about 3300 ft (1000 m).

The tectonic significance of conglomerate in the White River Formation is not as clear cut. This debris was derived mainly from the Wind River Range to the west and south and was deposited in a basin flanked by the dip slopes of the Wind River Range and the hanging wall of the Beaver

Figure 7—Surface of Pacific Butte showing boulders as large as 15 ft (4.5 m) in diameter left as a lag from weathering of the Cathedral Bluffs Tongue of the Wasatch Formation. Trace of the Continental fault (which uplifted the source for these clasts) is immediately behind the ridge (X). Pack on boulder shows scale.

Creek thrust (Figure 3). Whether deposition of this Oligocene conglomerate resulted from continued denudation of the original uplift or from renewed uplift is not entirely clear, but the disconformity between the White River and the subjacent Wasatch suggests that uplift was renewed. If this was the case, the White River conglomerate, together with the South Pass, provides one line of evidence that, in the Wind River Range, Laramide uplift lasted long after early Eocene time.

Tectonic implications of the Leckie beds are, at this time, necessarily sketchy. Little is known of them, but it seems clear that distinct alluvial fans were shed from locally uplifted blocks in the core of the range (Figure 3). The geomorphic expression of the fans can still be easily recognized on topographic maps and from the air. A more specific determination of their significance awaits further study.

The recognition of the northern side of the Continental fault as a source for Cathedral Bluffs sediments during early Eocene time is a particularly significant finding. Prior to this study, the Continental fault was recognized as a down-to-the-north, postcompressional collapse fault. The fact that the north side was apparently up during part of the time when the Wind River Range was thrust southwestward suggests that the early Eocene Continental fault served as a tear that uncoupled the range on the north from the basins to the south. Coarse latest Cretaceous and Paleocene deposits were probably also deposited along this zone of tearing during earlier phases of thrusting, but except for a Paleocene boulder bed in the subsurface south of the Bison basin, rocks of this age are not exposed in this area.

Finally, the Circle Bar beds represent the first sedimentologic evidence of the collapse of the Wind River Range along the Continental fault. There has never been much doubt that collapse did occur because Eocene sediments on the south are juxtaposed against Miocene sediments on the north. The Circle Bar beds, however, were shed by the high-standing south side of the fault during collapse in mid-Miocene time.

CONCLUSIONS

Data from the tectogenic sediments shed by the Wind River Range can be used to determine the details of its uplift and subsequent collapse. The subregional clastic apron that encircles the range records general uplift of the range along the Wind River fault, and intramontane alluvial deposits indicate significant uplift in the core after major movement on the Wind River fault ceased. Fault scarp clastic wedges identify both a steep tear fault that uncoupled the range from basins to the south and later collapse of the range along this same steep fault.

ACKNOWLEDGMENTS

This project was supported by National Science Foundation Grant no. EAR-8108939 to Steidtmann and Middleton and by the Amoco Production Company, Denver, Colorado.

REFERENCES CITED

Abbott, P. L., and G. L. Peterson, 1978, Effects of abrasion durability on conglomerate clast populations: examples from Cretaceous and Eocene conglomerates of the San Diego area, California: Journal of Sedimentary Petrology, v. 48, p. 31–42.

Allen, J. R. L., 1967, Depth indicators of clastic sequences: Marine Geology, v. 5, p. 429–446.

Berg, R. R., 1961, Laramide tectonics of the Wind River Mountains: Wyoming Geological Association 16th

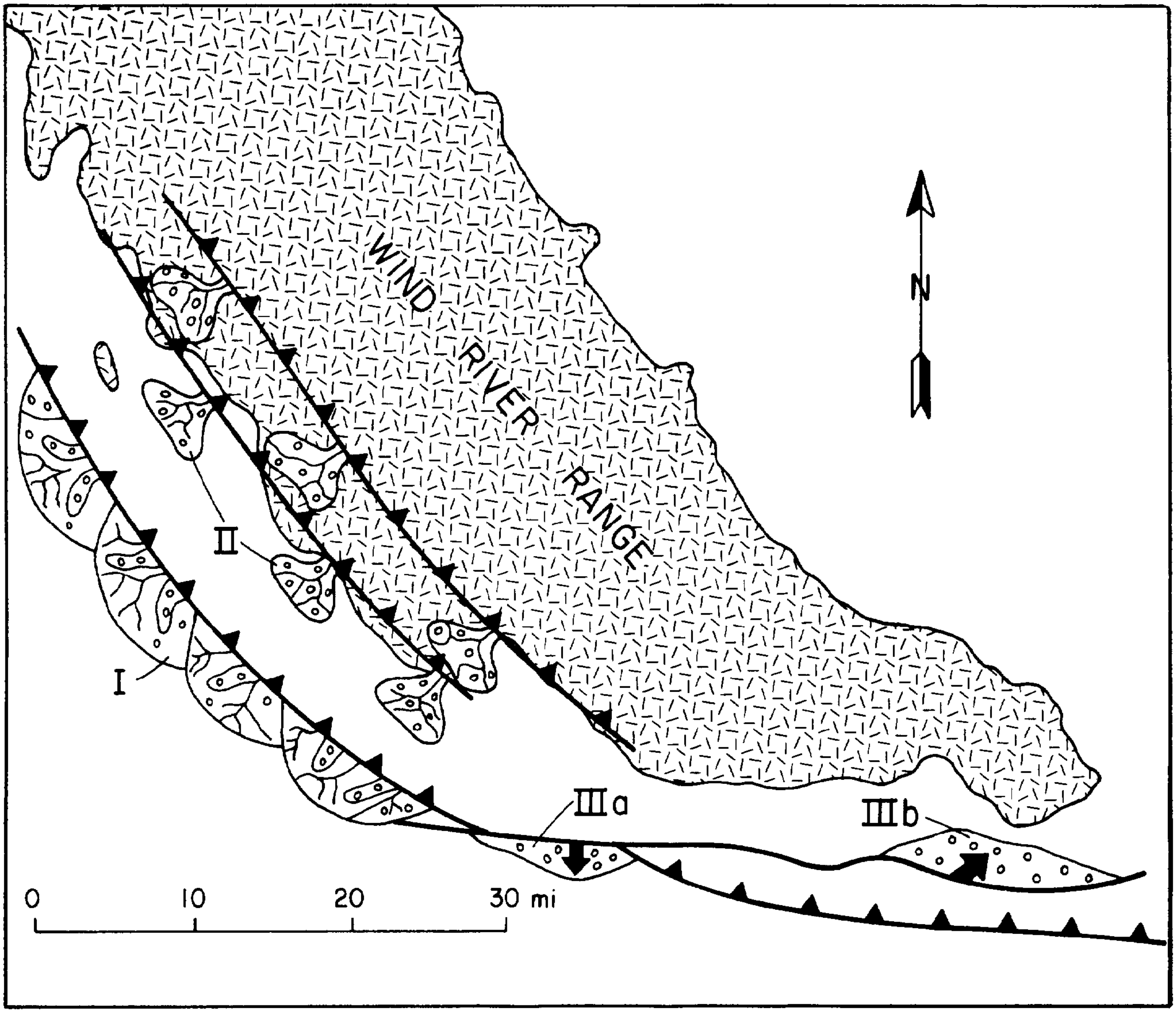

Figure 8—Schematic diagram showing the general distribution of the three types of conglomeratic units and their relationships to major structural elements. Type I deposits are the subregional clastic aprons along the main range-bounding fault zone. Type II are intramontane alluvial deposits associated with faulting in the core of the range. Type III are fault scarp clastic wedges. Type IIIa is related to tear faulting during compression and was transported southward. Type IIIb is related to postcompressional collapse of the range along the zone of tearing and was transported to the north.

Annual Conference Guidebook, p. 70–80.

———, 1963, Geometry of the Wind River thrust, *in* J. D. Lowell and R. Gries, eds., Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists Guidebook, p 257–262.

———, 1983, Laramide sediments along Wind River thrust, Wyoming, *in* O. E. Childs and B. W. Beebe, eds., Backbone of the Americas: AAPG Memoir 2, p. 220–230.

Bluck, B. J., 1967, Deposition of some upper Old Red Sandstone conglomerates in the Clyde area: a study in the significance of bedding: Scottish Journal of Geology, v. 3, p. 139–167.

———, 1979, Structure of coarse grained braided stream alluvium: Transactions of the Royal Society of Edinburgh, v. 70, p. 181–221.

Bottjer, R. J., 1984, Depositional environments and tectonic significance of the South Pass Formation, southern Wind River Range, Wyoming: Master's thesis, University of Wyoming, Laramie, 229 p.

Brewer, J. A., S. B. Smithson, J. E. Oliver, S. Kaufman, and L. D. Brown, 1980, The Laramide orogeny: evidence from COCORP deep crustal seismic profiles in the Wind River Mountains, Wyoming: Tectonophysics, v. 62, p. 165–189.

Collinson, J. D., 1978, Alluvial sediments, *in* H. G. Reading, ed., Sedimentary environments and facies: New York, Elsevier, p. 15–60.

Couples, G., and D. W. Stearns, 1978, Analytical solutions applied to structures of the Rocky Mountains foreland on local and regional scales, *in* V. Matthews, ed., Laramide folding associated with basement block

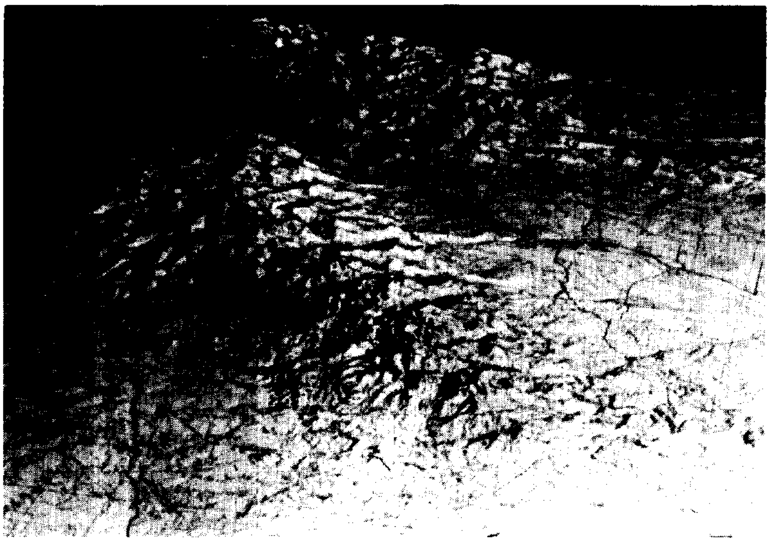

Figure 9—Oblique view of plastic relief map (2° sheets) of the northwestern quarter of Wyoming. Arrow points to the break in slope just west of the crest in the range that is probably the surface expression of a zone of faulting. Uplift along these faults supplied clasts to the South Pass conglomerate.

faulting in the western United States: Geological Society of America Memoir 151, p. 313–336.

Denson, N. M., and G. N. Pipiringos, 1974, Geologic map and sections showing areal distribution of Tertiary rocks near the southeastern terminus of the Wind River Range, Fremont and Sweetwater counties, Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I-835.

Hein, F. J., and R. G. Walker, 1977, Bar evolution and development of stratification in the gravelly, braided, Kicking Horse River, British Columbia: Canadian Journal of Earth Science, v. 14, p. 562–570.

Jackson, K. E., 1984, Geology of the Circle Bar Lake quadrangle, Fremont and Sweetwater counties, Wyoming: Master's thesis, University of Wyoming, Laramie, 77 p.

Larsen, V., and R. J. Steel, 1978, The sedimentary history of a debris-flow dominated, Devonian alluvial fan: a study of textural inversion: Sedimentology, v. 25, p. 37–39.

Law, B. E., 1981, Section C–C′: subsurface and surface correlations of some Upper Cretaceous and Tertiary rocks, northern Green River basin, Wyoming: U.S. Geological Survey Open-File Report 81-663.

Lieblang, S., 1983, Sedimentology and petrology of conglomerate and sandstone in the Oligocene White River Formation, central Wyoming: Master's thesis, Northern Arizona University, Flagstaff, 177 p.

Love, J. D., J. C. Anteweiler, and E. L. Mosier, 1978, A new look at the origin and volume of the Dickie Springs–Oregon Gulch placer gold at the south end of the Wind River Mountains: Wyoming Geological Association 30th Annual Field Conference Guidebook, p. 379–391.

MacLeod, M. K., 1981, The Pacific Creek anticline: buckling above a basement thrust fault: Wyoming University Contributions to Geology, v. 19, p. 143–160.

Martin, W. B., and J. Shaughnessy, 1969, Project Wagon Wheel: Wyoming Geological Association 21st Annual Field Conference Guidebook, p. 145–153.

McGee, L. C., 1983, Tectonics and sedimentation at Red's Cabin monocline, south end of the Wind River Range, Wyoming: Master's thesis, University of Wyoming, Laramie, 107 p.

Miall, A. D., 1977, A review of the braided-river depositional environment: Earth Science Review, v. 13, p. 1–62.

Moss, J. H., and W. G. Holmes, 1955, Pleistocene geology of the southwestern Wind River Mountains, Wyoming: Geological Society of America Bulletin, v. 66, p. 629–654.

Ore, H. T., 1963, The braided stream depositional environment: Ph.D. thesis, University of Wyoming, Laramie, 182 p.

Richmond, G. M., 1945, Geology of northwest end of the Wind River Mountains, Sublette County, Wyoming: U.S. Geological Survey Oil and Gas Investigation Series Map 31.

———, 1983, Modification of glacial sequence along Big Sandy River, southern Wind River Range, Wyoming (abs.): Geological Society of America Abstracts with Programs, Rocky Mountain–Cordilleran Sections, p. 431.

Roehler, H. W., 1969, Stratigraphy and oil-shale deposits of Eocene rocks in the Washakie basin: Wyoming Geological Association 21st Annual Field Conference Guidebook, p. 197–206.

Smith, D. G., and P. E. Putnam, 1980, Anastomosed river deposits: modern and ancient examples in Alberta, Canada: Canadian Journal of Earth Science, v. 17, p. 1396–1406.

Smith, N. D., 1970, The braided stream depositional environment: comparison of the Platte River with some Silurian clastic rocks, north-central Appalachians: Geological Society of America Bulletin, v. 81, p. 2993–3014.

Southard, J. B., 1971, Representations of bed configurations in depth–velocity size diagrams: Journal of Sedimentary Petrology, v. 41, p. 903–915.

Southwell, E. H., in prep., Depositional and pedogenic processes of the Fort Union Formation, Bison basin, central Wyoming: Master's thesis, University of Wyoming, Laramie.

Steel, R. J., 1974, New Red Sandstone floodplain and piedmont sedimentation in the Hebridean Province, Scotland: Journal of Sedimentary Petrology, v. 44, p. 336–357.

Steel, R. J., and D. B. Thompson, 1983, Structures and textures in Triassic braided stream conglomerates ("Bunter" Pebble Beds) in the Sherwood Sandstone Group, North Staffordshire, England: Sedimentology, v. 30, p. 341–368.

Steidtmann, J. R., and L. T. Middleton, 1986, Eocene–Pliocene stratigraphy along the southern margin of the Wind River Range, Wyoming: Revisions and implications from field and fission-track studies: The Mountain Geologist, v. 23, p. 19–25.

Steidtmann, J. R., L. C. McGee, and L. T. Middleton, 1983, Laramide sedimentation, folding and faulting in the southern Wind River Range, Wyoming, *in* J. D. Lowell and R. Gries, eds., Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists Guidebook, p. 161–168.

Winterfeld, G. F., 1979, Geology and mammalian paleontology of the Fort Union Formation, eastern Rock Springs uplift, Sweetwater County, Wyoming: Master's thesis, University of Wyoming, Laramie, 181 p.

Zeller, H. D., and E. V. Stephens, 1969, Geology of the Oregon Buttes area, Sweetwater, Sublette, and Fremont counties, southwestern Wyoming: U.S. Geological Survey Bulletin 1256, 60 p.