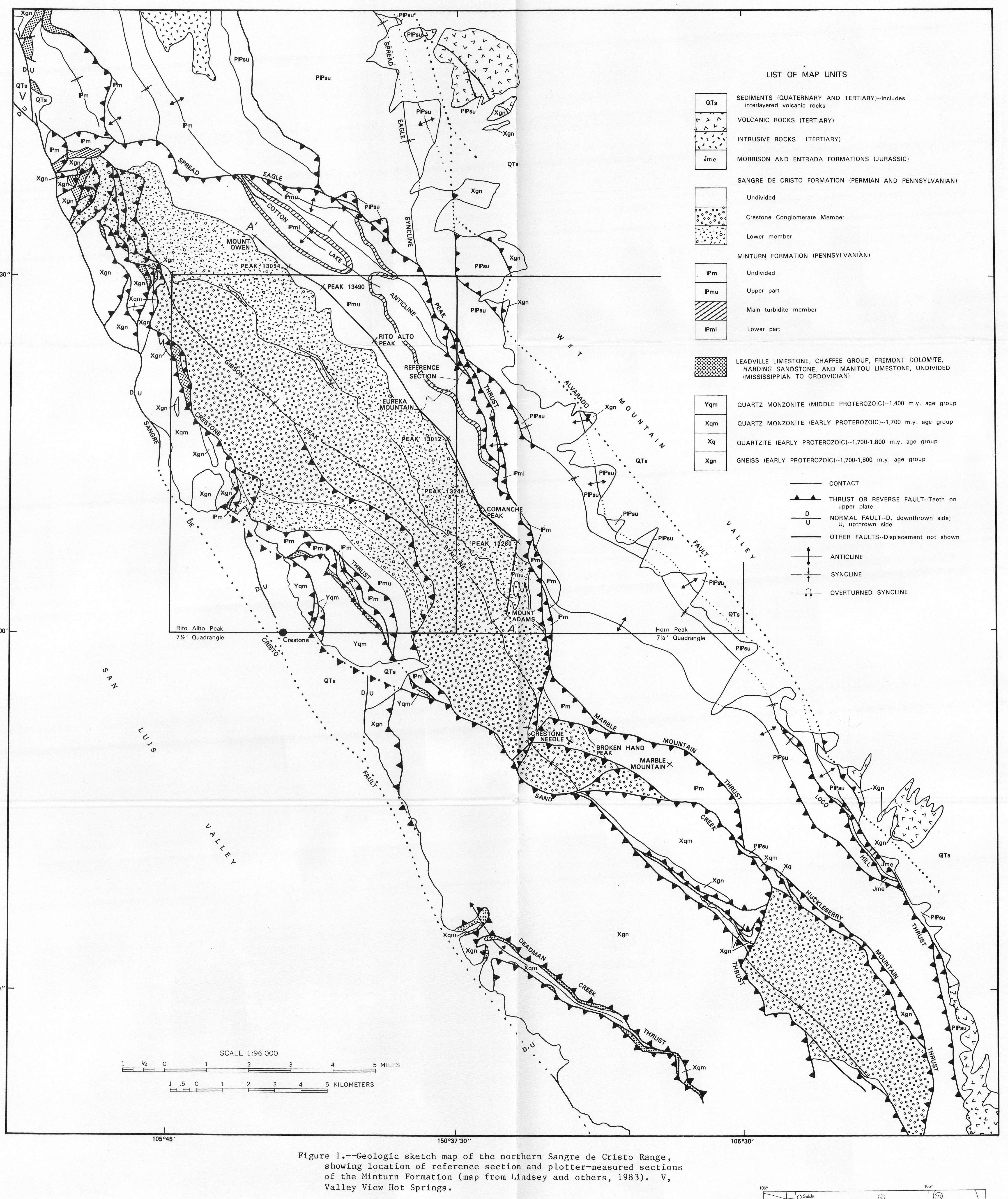
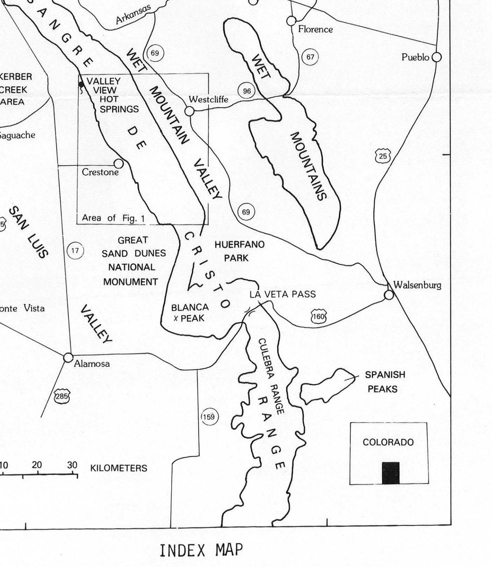


Figure 1.--Geologic sketch map of the northern Sangre de Cristo Range, showing location of reference section and plotter-measured sections of the Minturn Formation (map from Lindsey and others, 1983). V, Valley View Hot Springs.



INDEX MAP

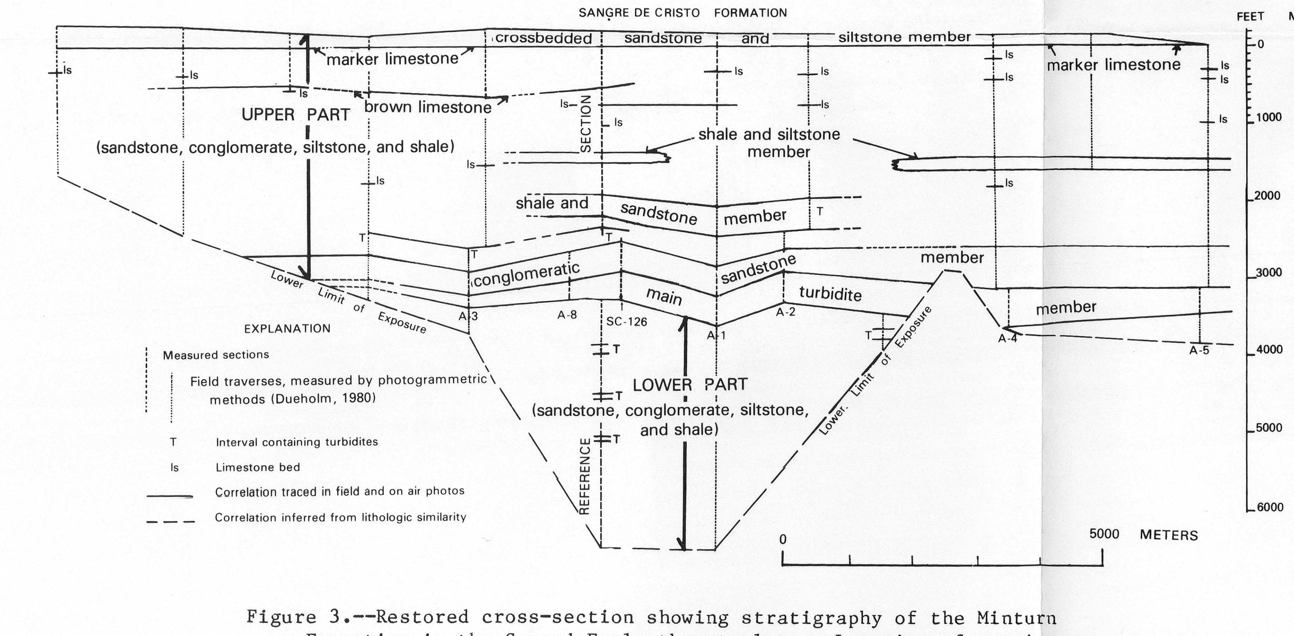


Figure 3.--Restored cross-section showing stratigraphy of the Minturn Formation in the Spread Eagle thrust plate. Location of section shown on figure 1.

INTRODUCTION

This reference section of the Middle Pennsylvanian Minturn Formation was measured in the northern Sangre de Cristo Range; the section provides a basis for comparison with the type Minturn and with possibly equivalent strata elsewhere in southern Colorado. The name "Minturn" was first applied to strata of Middle Pennsylvanian age near the town of Minturn in central Colorado (Tweto, 1949, p. 194-228; Tweto and Lovering, 1977, p. 33-53), about 180 km north of the section described, and has been extended to strata of approximately the same age that contain marine limestones in the northern Sangre de Cristo Range (Brill, 1952; Bolyard, 1959; Scott and Taylor, 1974). The Minturn reference section continues upward into the principal reference section of the overlying Pennsylvanian and Permian Sangre de Cristo Formation (Lindsey and Schaefer, 1984), and these two sections together provide a continuous record of upper Paleozoic strata in the northern Sangre de Cristo Range.

The reference section was measured by tape and compass in the summer of 1980; observations were recorded on a microcassette tape recorder in the field and transcribed in the office. This method permitted rapid acquisition of data on thickness, nature of contacts, color, grain size, and sedimentary features. These data are shown on the graphic section for each distinct rock unit. Rock units having common attributes or genetic relationships have been grouped together for descriptive and interpretative purposes.

LOCATION AND GEOLOGIC SETTING

The reference section is located east of the crest of the northern part of the Sangre de Cristo Range, in the Horn Peak and Rito Alto Peak 7 1/2-minute quadrangles of south-central Colorado (fig. 1). The section extends along the ridge south of Middle Taylor Creek from the east side of peak 12,193 to the summit of Eureka Mountain, at the crest of the range (fig. 2); it is accessible by foot from the Hermit road by Middle Taylor Creek. The best exposures of the Minturn Formation are along the north side near the crest of the ridge, where a continuous, almost totally exposed section was measured. The top of the Minturn Formation is well-exposed at the reference section, but the base of the reference section is cut by the Spread Eagle Peak thrust and its branches (fig. 1). Branches of the thrust at 132 and 317 m above the main thrust have small displacement, judging from detailed mapping (fig. 2), so their effect on the thickness of the section is minor. About 1,990 m of Minturn Formation is exposed in the reference section along Middle Taylor Creek.

The reference section is located in the Spread Eagle Peak thrust plate, one of the largest thrust plates in the northern Sangre de Cristo Range (fig. 1) (Lindsey and others, 1983). Thinner, faulted sections of Minturn are exposed near the village of Crestone on the west side of the Spread Eagle Peak plate, at Marble Mountain in the Marble Mountain plate, and in autochthonous terrane to the north of the Spread Eagle Peak plate.

The upper Paleozoic strata of the thrust plates share general stratigraphic similarities, but strata of each plate also contain distinctive features. The Minturn Formation of the reference section contains thin beds of shallow-marine limestone in the upper 500 m and, below the calcareous interval, lenses of sandstone deposited by turbidity flows. In contrast, the Minturn of the Marble Mountain plate contains shallow-marine limestones throughout and no lenses of turbidite sandstones. The calcareous interval in the upper part of the Minturn reference section occurs also near Crestone, on the west side of the range, and in autochthonous terrane to the north and south of the reference section; no turbidites have been identified below the calcareous interval of the Minturn in these areas.

PREVIOUS WORK

The names "Arkansas sandstone" (Endlich, 1874, p. 326-329) and "Sangre de Cristo Formation" (Hills, 1899; Melton, 1925) were once applied to the entire section of upper Paleozoic strata in the northern part of the Sangre de Cristo Range. After Tweto (1949, p. 194-206) named and described the Minturn Formation in central Colorado, other workers (Brill, 1952; Litsey, 1958; Bolyard, 1959; Scott and Taylor, 1974) extended the name to the northern Sangre de Cristo Range. Bolyard (1959, p. 1919-1922) measured and briefly described the reference section of this report, and restricted the use of the name "Minturn" to strata north of Marble Mountain (fig. 1); he applied the name "Madera" to equivalent strata south of there because he believed that they resemble the Pennsylvanian Madera Formation of New Mexico. We apply the name "Minturn" to all strata that are considered equivalent to the reference section and that occur in the Sangre de Cristo Range, regardless of regional variations in facies. Mapping of the range from Blanca Peak to the Arkansas River shows that these strata share similar features and are laterally continuous except where cut by thrusts (Johnson and others, 1985). The name "Minturn" has been used on detailed geologic maps as far south as La Veta Pass (Vine, 1974).

THICKNESS, CONTACTS, AND INFORMAL MEMBERS

The Minturn reference section is about 1,990 m thick; the lower part of the Minturn is progressively cut out by the Spread Eagle Peak thrust north and south of the line of the section (fig. 3). The original thickness of Minturn at the reference section is unknown, but probably does not greatly exceed the exposed thickness because a much greater thickness of undeformed Minturn has not been recorded elsewhere in the range. An estimated thickness of 2,440 m in the northern part of the range (Litsey, 1958, p. 1160) may be excessive because of structural complications; a thickness of 1,680 m was estimated for the Minturn near Valley View Hot Springs (DeVoto and Peel, 1972, p. 297) and only 1,280 m of Minturn was measured in the Arkansas River Valley (Brill, 1952, p. 878), about 50 km north of the reference section. The base of the Minturn is exposed in the autochthonous terrane of the northern part of the range, where it conformably overlies shale and sandstone correlated with the Pennsylvanian Belden Formation (Taylor and others, 1975). The top of the Minturn is conformably overlain by the Pennsylvanian and Permian Sangre de Cristo Formation in the Spread Eagle Peak plate and in autochthonous terrane to the north and south.

The reference section contains marker beds and members that can be traced along strike in parts of the Spread Eagle Peak thrust plate, but which are lenticular and grade laterally into other facies (fig. 3). These marker beds and members are informal because they have only local significance. In ascending stratigraphic order, these units are (1) the main turbidite member (unit 46, 124 m thick, 906 m above base of section), (2) the conglomeratic sandstone member (units 47-52, 107 m thick, 1,032 m above base of section), (3) a shale and sandstone member (units 58-63, 90 m thick, 1,244 m above base of section), (4) a shale and siltstone member (units 71-74, 47 m thick, 1,458 m above base of section), (5) the brown limestone (unit 95, 2.5 m thick, 1,761 m above base of section), (6) the marker limestone (upper part of unit 104, 0.8 m thick, 1,922 m above base of section), and (7) the crossbedded sandstone and siltstone member (unit 105, 64 m thick, 1,923 m above base of section). The main turbidite and conglomeratic sandstone members have been traced more than 13 km along strike (Soulliere and others, 1984), and the overlying shale and siltstone member crops out as two lenses 3 and 5 km long. The brown limestone has been traced for 8 km, mostly south of the reference section; and the marker limestone and overlying crossbedded sandstone and siltstone member have been traced 13 km and correlated with beds extending 5 km farther south (Clark and Walz, 1985). No beds that could be traced more than 2 km were identified below the main turbidite, probably owing to their lenticular shape. No units have been correlated with certainty across thrust faults, although the marker limestone was tentatively correlated with the top thick fossiliferous limestone in autochthonous Minturn strata east and north of the Spread Eagle Peak thrust (Clark and Walz, 1985).

FOSSILS AND AGE

All the strata of the Minturn Formation reference section are regarded as Middle Pennsylvanian (Atokan and Desmoinesian) age, in agreement with the age assigned to the type section (Tweto and Lovering, 1977, p. 48). No fossils of chronostratigraphic significance have been found in the lower part of the Minturn in the Spread Eagle Peak thrust plate, but Beedeina sp. (formerly Fusulina sp.) of Desmoinesian age (R. C. Douglass, written commun., 1983) occurs in limestone bioherms in the lower part of the Minturn on Marble Mountain, in the Marble Mountain thrust plate. Limestones in the calcareous upper 500 m of the Minturn of the Spread Eagle Peak plate have yielded fusulinids of Beedeina sp. of Desmoinesian age (R. C. Douglass, written commun. 1981); one of these limestones, on the east spur of Mt. Adams, is correlated with the marker limestone. The marker limestone (upper part of unit 104) of the Minturn reference section also contains a conodont fauna that has been assigned an Atokan age (B. R. Wardlaw, written commun., 1980, 1982). Limestone beds in the lower member of the Sangre de Cristo Formation, located above the Minturn marker limestone west of Mt. Owen, contain conodonts of Atokan or Desmoinesian age (B. R. Wardlaw, written commun., 1982). Other marine fossils in the Minturn and lower Sangre de Cristo limestones include brachiopods and crinoid columnals, but they are of no use in refining the age of the strata as established by fusulinids and conodonts; however, the presence of brachiopods and crinoids do confirm the intermittent presence of shallow marine conditions. Until the inconsistency between ages assigned from fusulinids and conodonts is resolved, the Minturn reference section is regarded as Atokan and Desmoinesian.

Casts of trunks and stems of Calamites sp. and leaf impressions of Neuropteris sp. and Cordaites sp. (all identified by R. M. Kosanke, oral commun., 1982) occur in alluvial and delta-plain deposits in both the upper and lower parts of the Minturn in the Spread Eagle Peak plate. Although not definitive of the age of the strata, these plants are consistent with a Pennsylvanian age, and they indicate the occurrence, at least locally, of coal-swamp vegetation.

DEPOSITIONAL ENVIRONMENTS

The Minturn Formation of the reference section is interpreted as numerous stacked fan-delta deposits formed by alluvial fans that prograded into the Middle Pennsylvanian seas of the central Colorado trough. The term "fan delta" is used here to refer to a deltaic deposit formed by an alluvial fan prograding into standing water (Holmes, 1965, p. 554). Sediments of the Minturn consist mostly of coarse alluvial and deltaic deposits that interfinger with prodelta marine strata; sediment dispersal was for the most part directed northeasterly (perpendicular to shoreline) by alluvial systems. The Minturn at the reference section is conformably overlain by coarse alluvial-fan deposits of the Sangre de Cristo Formation (Lindsey and Schaefer, 1984).

Models of prograding fan-delta systems depositing coarse detritus have been proposed for the calcareous interval of the upper Minturn in the region of the reference section (Clark, 1982), for strata of Pennsylvanian and Permian age in the southern part of the Sangre de Cristo Range (Casey and Scott, 1979; Casey, 1980), and for Cretaceous and Paleocene strata in northeastern Mexico (McBride and others, 1975). These depositional models, and those for large river deltas (Wright, 1978), provide a basis for interpretation of the Minturn reference section, but none of these models can be applied to the Minturn without modification. Interpretation of individual depositional environments in the Minturn reference section relies mainly on associations of sedimentary structures and sequences of facies; evidence from fossils is sparse, but is of first importance where present.

Strata of the reference section are organized into complex cycles that are interpreted to have been deposited by prograding fan-delta systems. Two types of prograding fan-delta cycles have been identified. Cycles produced by deltas prograding onto the sea floor, mostly below wave base, are present in the lower 1,500 m of the Minturn reference section. Cycles produced by deltas prograding onto shallow marine shelves, mostly above wave base, are present in the upper 500 m of the reference section. The two cycles probably represent differences in the gradient and proximity of onshore alluvial systems, position of shorelines, slope and depth of the sea floor, and coastal wave energy.

A typical Minturn deltaic cycle that prograded below wave base consists of (1) prodelta shale, siltstone, and sandstone; (2) prodelta or delta-front sandstones deposited by turbidity flows; (3) delta-front deposits of conglomeratic sandstone; and (4) delta-plain and alluvial-plain channel sandstone and overbank siltstone and shale, arranged in fining-upward subcycles. Sandstones of facies (2) through (4) are coarse-grained and conglomeratic. The thickness of each facies in a cycle varies, but the fine-to-coarse-to-fine grain size of the cycle is generally evident. The slope of the delta front may have been too steep, or wave energy may have been too weak, to develop a broad zone of reworking by marine waves and currents. Laterally extensive deposits of the zone of coastal reworking, such as hummocky cross-stratification (Harms and others, 1982), have not been identified, although further study might reveal that they occur locally. Marine prodelta and delta-front deposits show a pronounced and regular coarsening- and thickening-upward trend. Intervals of turbidites indicate deposition below wave base, but fossils diagnostic of marine environments are lacking.

A good example of a prograding cycle is shown by units 45-52 (cycle V). Unit 45 may represent prodelta siltstone and shale; it contains sparse pelecypods on the ridge south of the reference section, but no fossils diagnostic of marine environments. Unit 46 is a 124-m-thick sequence of turbidite sandstones (Soulliere and others, 1984); it is coarse grained, even conglomeratic locally, contains Bouma cycles (Bouma, 1962) and well-developed graded and massive intervals typical of turbidites considered by Walker (1967) to be proximal to the source of turbidity flows, and was deposited as a broad fan extending more than 13 km along the depositional strike (Soulliere and others, 1984). Units 47, 48, and 50 represent 75 m of prograding delta-front deposits of mostly crossbedded conglomeratic sandstone deposited by northeasterly paleocurrents aligned with those that deposited the underlying turbidite sandstones. The conglomeratic sandstone is a laterally extensive body that may represent coalescing distributary-mouth bars formed by braided distributaries in the manner suggested by Wright (1978, p. 48) for high-bed-load rivers. The red-gray siltstone of unit 49 may record temporary submergence during abandonment by the distributary channel; the upper part of unit 50, and units 51 and 52 may record deltaic and alluvial-plain sedimentation.

Variations of the deltaic cycle in the lower Minturn contain few or no sandstone beds deposited by turbidity flows. Units 22-29 (cycle II) comprise a coarsening-upward sequence containing only a thin (16 m) interval of thin-bedded turbidites(?) (unit 23) overlying prodelta siltstone and shale (unit 22). The turbidites(?) pass transitionally upward into 44 m of thick-bedded, crossbedded conglomeratic sandstone (unit 24) interpreted as a delta-front deposit; along strike, these delta-front beds contain large-scale (5 m) foresets deposited by a small delta in shallow water. Unit 26 is interpreted as a deltaic or alluvial-plain overbank deposit having a weakly developed calcareous soil(?). Interpretation of calcareous horizons here and in units 11 and 66 as paleosoils is problematical; profiles diagnostic of paleosoils (Steel, 1974) are not well developed in the few nonmarine calcareous intervals observed in the Minturn reference section. Units 27-30 record deposition of coarse detritus by distributaries at the delta front or by braided streams onshore.

Intervals of probable delta-plain and alluvial sediment overlie most of the prograding delta cycles described previously. Units 4-21 and 56-70 are interpreted as thick intervals of delta-plain and alluvial sediments; they consist of alternating sandstone and shale, some arranged in fining-upward sequences resembling deposits of meandering streams summarized by Miall (1981, p. 32-38). Delta-plain and alluvial deposits in the reference section are characterized by abundant siltstone and shale, by lenticular and channel-like sandstone geometry, by facies changes from small channels filled with sandstone to thin crevasse-splay(?) sandstone and overbank siltstone and shale, and by sparse evidence of emergence, such as plant remains in growth position and calcareous horizons of possible pedogenic origin. Channel sandstones are interpreted as deposits of small distributaries or ephemeral streams. Mudcracks are not seen, probably because most alluvial plains of Minturn time were vegetated, as shown by remains of plants.

A laterally extensive shale and siltstone member (units 71-74) may be a lacustrine deposit; alternatively, the member may have been deposited during a sudden marine transgression. The member occurs between alluvial deposits but has abundant siltstone laminae and thin beds having rippled tops, all features unlikely to have been preserved in a subaerial environment; the member is not known to contain marine fossils.

Sediment deposited by fan deltas prograding onto a shallow marine shelf comprise the upper 500 m of the Minturn Formation at the reference section (Clark, 1982; Clark and Walz, 1985). These sediments are arranged in cycles composed of, from bottom to top, (1) prodelta and interdeltaic shallow-marine limestone, shale, siltstone, and sandstone, (2) delta-front conglomerate and conglomeratic sandstone, locally containing large deltaic foresets deposited by distributaries discharging into shallow water, and (3) fining-upward subcycles of sandstone, siltstone, and shale deposited by braided streams. Fossiliferous marine limestones and burrowed sandstones and siltstones represent intervals between delta progradation when local submergence occurred, possibly in response to switching of delta lobes. These marine deposits separate cycles of deltaic deposition. Features indicative of delta-front environments are difficult to detect in many cycles; some cycles may be composed almost entirely of shallow-marine and braided-stream facies. Some delta-front deposits contain large tabular foresets formed by small deltas prograding into standing water, similar to the lacustrine deltas described by Gilbert (1883) and the deltaic sedimentation units of Collinson (1968). The thickness of deltaic crossbed sets, generally less than 5 m, is a rough estimate of the depth of the body of standing water. Calcareous siltstone, siltstone, and shale interpreted as interdistributary bay deposits interfinger with delta-front deposits along strike from the reference section. Bay deposits of the upper Minturn commonly contain evidence, such as accumulations of plant trash, of stagnant conditions; in some cases, bay deposits adjoin prodelta marine deposits and subaerial delta-plain deposits having plant trunks in growth position. Above the delta-front deposits, local overbank deposits of shale and siltstone in the braided alluvial facies contain casts of Calamites, some in growth position. Cyclic fan-delta deposits similar to those of the upper Minturn Formation have been described from sediments of Desmoinesian age in the southern part of the Sangre de Cristo Range (Casey and Scott, 1979).

A good example of a deltaic cycle that prograded onto a shallow marine shelf above wave base is shown by units 95-103 (cycle X). The brown limestone (unit 95) contains fossils of shallow-water marine invertebrates, marking submergence of the previous fan delta. The brown limestone is overlain by unit 96, composed of progressively coarser and thicker-bedded siltstone and sandstone containing plant fragments, and conglomeratic sandstone containing large deltaic foresets; this sequence represents shallow-marine prodelta, delta-front, and possibly braided-alluvial deposits. Units 97-103 are composed of crossbedded sandstone, much of it conglomeratic and interbedded with bioturbated sandstone and siltstone; this part of the sequence may represent alternating of braided-stream and delta-front environments. The site of the fan delta was reoccupied by the sea when the marker limestone (unit 104) was deposited.

CONCLUSIONS

About 2,000 m of Middle Pennsylvanian Minturn Formation is exposed in a continuous section in the east part of the Spread Eagle Peak thrust plate in the northern Sangre de Cristo Range. This section is designated here as a reference section for comparison with equivalent strata nearby. Strata of the Minturn reference section are interpreted as a series of stacked fan-delta deposits that formed in the central Colorado trough along the northeast side of the Uncompahgre-San Luis highland in Middle Pennsylvanian time. Strata of the lower 1,500 m of the reference section are composed of cyclic sequences containing interbedded fluvial and deltaic deposits and intervals of turbidites, all deposited by fan deltas that prograded in water that was mostly below wave base. Strata of the upper 500 m of the reference section are composed of cyclic sequences of interbedded alluvial and deltaic clastic sediments and shallow-marine limestones; these sequences were deposited by fan deltas that prograded into shallow seas above wave base.

REFERENCES CITED

Brill, K. G., Jr., 1952, Stratigraphy in the Permo-Pennsylvanian zeugogeosyncline of Colorado and northern New Mexico: Geological Society of America Bulletin, v. 63, no. 8, p. 809-880.
Bouma, A. H., 1962, Sedimentology of some flysch deposits--A graphic approach to facies interpretation: Amsterdam, Elsevier Publishing Company, 168 p.
Bolyard, D. W., 1959, Pennsylvanian and Permian stratigraphy in Sangre de Cristo Mountains between La Veta Pass and Westcliffe, Colorado: American Association Petroleum Geologists Bulletin, v 43, no. 8, p. 1896-1939.
Casey, J. M., 1980, Depositional systems and paleogeographic evolution of the Late Paleozoic Taos trough, northern New Mexico; in Fouch, T. D., and Magathan, E. R., eds., Paleozoic paleogeography of west-central United States, Paleogeographic Symposium I: Denver, Colo., Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, p. 181-189.
Casey, J. M., and Scott, A. J., 1979, Pennsylvanian coarse-grained fan deltas associated with the Uncompahgre uplift, Talpa, New Mexico; in Ingersoll, R. V., ed., Guidebook of Santa Fe Country: New Mexico Geological Society Guidebook, 13th Annual Field Conference, p. 211-218.
Clark, R. F., 1982, Stratigraphy, sedimentology and copper-uranium occurrences of the upper part of the middle Pennsylvanian Minturn Formation, Sangre de Cristo Mountains, Colorado: Golden, Colo., Colorado School of Mines, M.S. thesis, 151 p.
Clark, R. F., and Walz, D. M., 1985, Stratigraphic sections, depositional environments, and metal content of the calcareous upper part of the middle Pennsylvanian Minturn Formation, northern Sangre de Cristo Range, Custer and Saguache Counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1622-D.
Collinson, J. D., 1968, Deltaic sedimentation units in the upper Carboniferous of northern England: Sedimentology, v. 10, p. 233-254.
DeVoto, R. H., and Peel, F. A., 1972, Pennsylvanian and Permian stratigraphy and structural history, northern Sangre de Cristo Range, Colorado; in DeVoto, R. H., ed., Paleozoic stratigraphy and structural evolution of Colorado: Colorado School of Mines Quarterly, v. 67, no. 4, p. 283-320.
Dueholm, K. S., 1980, Computer-supported photointerpretation: Photogrammetria, v. 39, p. 159-171.
Endlich, F. M., 1874, Report of F. M. Endlich, in Hayden, F. V., Progress report of exploration for the year 1873: Annual Report of the United States Geological and Geographical Survey of the Territories, embracing Colorado, p., 275-351.
Gilbert, G. K., 1883, The topographic features of lake shores: U.S. Geological Survey 5th Annual Report, p. 69-123.
Harms, J. C., Southard, J. B., and Walker, R. G., 1982, Structures and sequences in clastic rocks: Society of Economic Paleontologists and Mineralogists Short Course no. 9.
Hills, R. C., 1899, Description of the Elmoro quadrangle [Colorado]: U.S. Geological Survey Geologic Atlas, Folio 58.
Holmes, Arthur, 1965, Principles of physical geology (2d ed.): New York, Ronald Press, 1288 p.
Johnson, B. R., Lindsey, D. A., Bruce, R. M., and Soulliere, S. J., 1985, Reconnaissance geologic map of the Sangre de Cristo wilderness study area, south-central Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1635-B, scale 1:62,500.
Lindsey, D. A., and Schaefer, R. A., 1984, Principal reference section for the Sangre de Cristo Formation (Pennsylvanian and Permian), northern Sangre de Cristo Range, Saguache County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1622-A.
Lindsey, D. A., Johnson, B. R., and Andriessen, P. A. M., 1983, Laramide and Neogene structure of the northern Sangre de Cristo Range, south-central Colorado; in Lowell, J. D., ed., Rocky Mountain foreland basins and uplifts: Denver, Colo., Rocky Mountain Association of Geologists, p. 219-228.
Litsey, L. R., 1958, Stratigraphy and structure of the northern Sangre de Cristo Mountains, Colorado: Geological Society of America Bulletin, v. 69, no. 9, p. 1143-1178.
Miall, A. D., 1981, Analysis of Fluvial Depositional Systems: American Association of Petroleum Geologists, Education Course Note Series, no. 20, 75 p.
McBride, E. F., Weide, A. E., and Wolleben, J. A., 1975, Deltaic and associated deposits of Difunta Group (Late Cretaceous to Paleocene), Parras and La Popa basins, northeastern Mexico; in Broussard, M. L., ed., Deltas, models for exploration: Houston, Texas, Houston Geological Society, p. 485-522.
Melton, F. A., 1925, Correlation of Permo-Carboniferous red beds in southwestern Colorado and northern New Mexico: Journal of Geology, v. 33, no. 8, p. 807-815.
Scott, G. R., and Taylor, R. B., 1974, Reconnaissance geologic map of the Electric Peak quadrangle, Custer and Saguache Counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-628, scale 1:62,500.
Soulliere, S. J., DeAngelis, B. L., and Lindsey, D. A., 1984, Measured sections and discussion of the main turbidite member, middle Pennsylvanian Minturn Formation, northern Sangre de Cristo Range, Custer and Saguache Counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1622-B.
Steel, R. J., 1974, Cornstone (fossil caliche)--Its origin, stratigraphic and sedimentological importance in the New Red Sandstone, western Scotland: Journal of Geology, v. 82, no. 3, p. 351-369.
Taylor, R. B., Scott, G. R., and Wobus, R. A., 1975, Reconnaissance geologic map of the Howard quadrangle, central Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-892, scale 1:62,500.
Tweto, Ogden, 1949, Stratigraphy of the Pando area, Eagle County, Colorado: Colorado Scientific Society Proceedings, v. 15, no. 4, p. 149-235.
Tweto, Ogden, and Lovering, T. S., 1977, Geology of the Minturn 15-minute quadrangle, Eagle and Summit Counties, Colorado: U.S. Geological Survey Professional Paper 956, 96 p.
Vine, J. D., 1974, Geologic map and cross sections of the La Veta Pass, La Veta, and Ritter Arroyo quadrangles, Huerfano and Costilla Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-833, scale 1:48,000.
Walker, R. G., 1967, Turbidite sedimentary structures and their relationship to proximal and distal depositional environments: Journal of Sedimentary Petrology, v. 37, no. 1, p. 25-43.
Wright, L. D., 1978, River deltas; in Davis, R. A., Jr., ed., Coastal sedimentary environments: New York, Springer, p. 5-68.

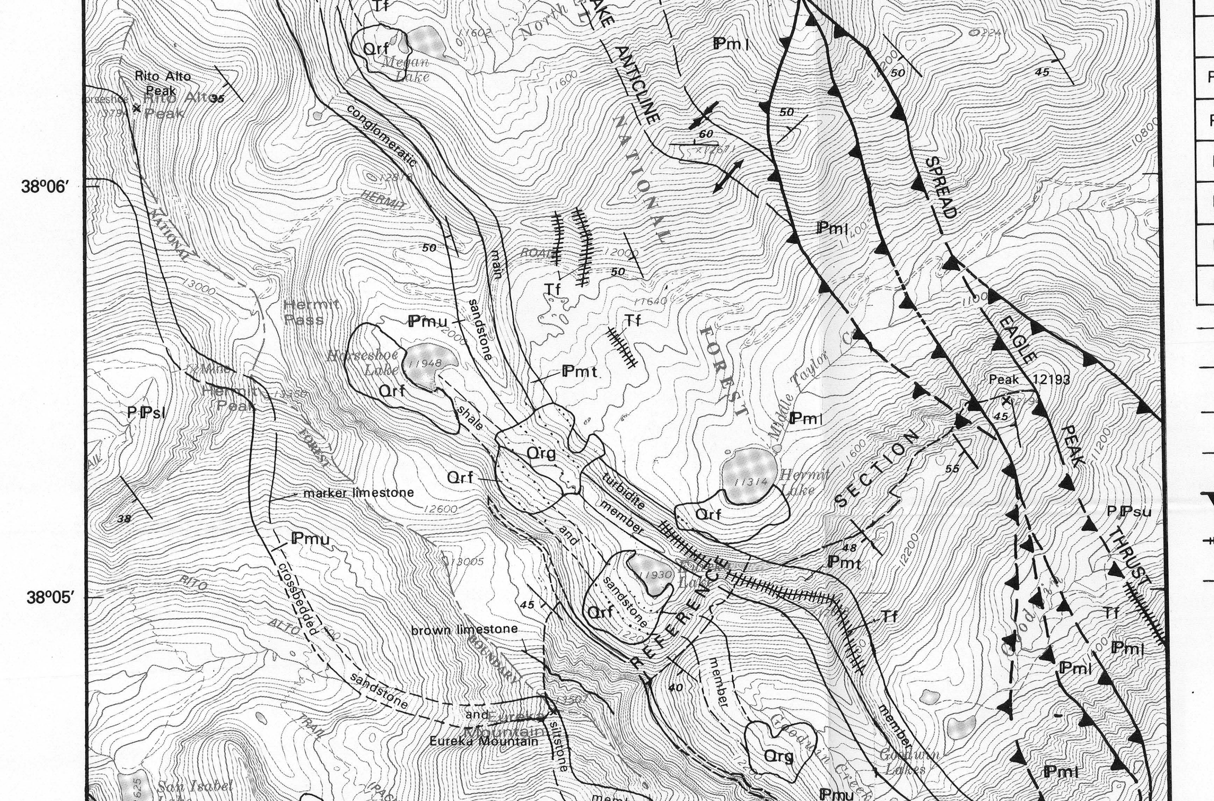


Figure 2.--Map showing local geologic features and line of measured reference section through the Minturn Formation.

EXPLANATION

- Qrf — ROCKFALL (QUATERNARY)
- Qrg — ROCK-GLACIER DEPOSITS (QUATERNARY)
- Tf — FELSIC IGNEOUS ROCK (TERTIARY)--Occurs as dikes and sills
- SANGRE DE CRISTO FORMATION (PERMIAN AND PENNSYLVANIAN)
  - PIPsu — Undivided
  - PIPsc — Crestone Conglomerate Member
  - PIPsl — Lower member
- MINTURN FORMATION (PENNSYLVANIAN)
  - IPmu — Upper part
  - IPmt — Main turbidite member
  - IPml — Lower part
- CONTACT--Dashed where located approximately, dotted where concealed
- ANTICLINE
- SYNCLINE
- STRIKE AND DIP OF BEDDING
- THRUST OR REVERSE FAULT--Dashed where approximately located; sawteeth on upper plate
- DIKE OR SILL
- MEASURED SECTION

REFERENCE SECTION FOR THE MINTURN FORMATION (MIDDLE PENNSYLVANIAN) NORTHERN SANGRE DE CRISTO RANGE, CUSTER COUNTY, COLORADO

By
D. A. Lindsey, R. F. Clark, and S. J. Soulliere

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