Geologic and Structure Map of the Choteau 1^o x 2^o Quadrangle, Western Montana: A Digital Database

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(map originally published in 1982)

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Introduction

The geologic and structure map of the Choteau 1^{o} x 2^{o} quadrangle (Mudge and others, 1982) was originally converted to a digital format by Jeffery T. Silkwood (U.S. Forest Service) and completed by U.S. Geological Survey and contractors at the Spokane Field Office (WA) in 2001 for input into a geographic information system (GIS). The resulting digital geologic map (GIS) database can be queried in many ways to produce a variety of geologic maps. Digital base map data files (topography, roads, towns, rivers and lakes, etc.) are not included: they may be obtained from a variety of commercial and government sources. This database is not meant to be used or displayed at any scale larger than 1:250,000 (for example, 1:100,000 or 1:24,000). The digital geologic map graphics and plot files (chot250k.gra/.hp/.eps and chot-map.pdf) that are provided in the digital package are representations of the digital database. They are not designed to be cartographic products.

The map area is located in western Montana (fig. 1). This report describes the geologic map units (Mudge and others, 1982), the methods used to convert the geologic map data into a digital format, the ArcInfo GIS file structures and relationships, and explains how to download the digital files from the U.S. Geological Survey public access World Wide Web site on the Internet.

Manuscript and digital data review by Gregory Green (USGS) is greatly appreciated.

Description of Map Units

The description of map units below is from Mudge and others (1982).

Qa Alluvial and colluvial deposits (Holocene and Pleistocene)—Unconsolidated stream-laid sand, gravel, and silt, bouldery, poorly to moderately well sorted. Includes alluvial fan, slope wash, colluvial and glacial outwash deposits of Bull Lake and younger in age. Thickness of deposits as much as 10 m.

Qs Landslide deposits (Holocene and Pleistocene)—Mostly rock debris, locally coarse angular rock fragments in silt or clay matrix. Forms hummocky topography. Produced by rockfall- and rockslide-avalanches, slump, and earthflow. Thickness possibly as much as 300 m.

Qg Glacial deposits (Holocene and Pleistocene)—Drift, heterogeneous mixture of rock fragments in silty clay matrix. Forms hummocky topography. Includes deposits from alpine and continental glaciations; as much as 100 m thick except in Swan River valley where thickness of mostly sand and gravel deposits exceed 300 m.

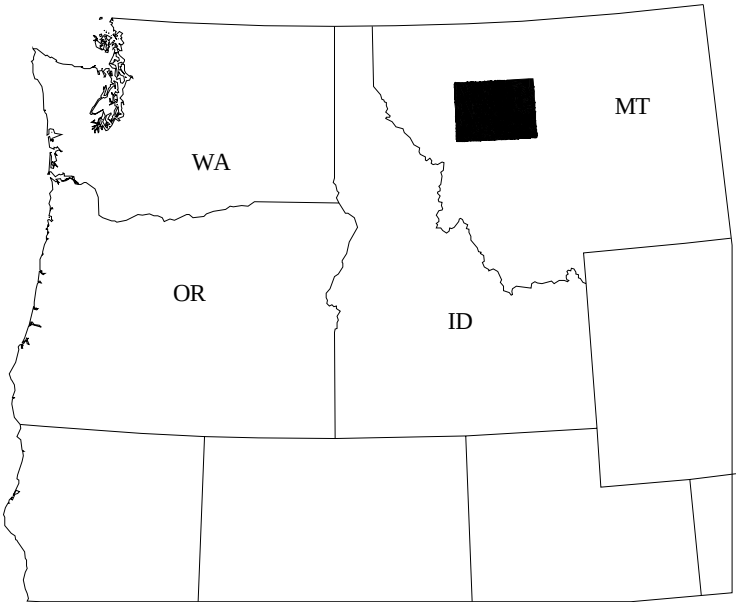

Figure 1. Index map showing the geographic extent of the Choteau quadrangle (black fill) with respect to the Pacific Northwest.

Ql Lake deposits (Pleistocene)—Light-gray to dark-gray and gray-brown, thin- to thick-bedded silty clay, clay, and some sand; deposited in glacial lakes. Thickness of deposits as much as 30 m.

Qtog Older gravel (Pleistocene and possibly Pliocene)—Coarse stream-laid gravel on remnants of at least four bench surfaces as much as 250 m above modern stream alluvium. Maximum thickness is about 10 m.

Tla Lake deposits (Miocene and Oligocene)—Gray, yellowish-gray, gray-brown, sandy silt, silt, clay, shale, marl, and some poorly sorted conglomerate; locally thin coal and carbonates. Locally includes wood and leaf fragments, insects, fish, gastropods, pelecypods, and ostracods. In Landers Fork, Blackfoot River includes tuff. Thickness possibly as much as 125 m.

Ksmr St. Mary River Formation (Upper Cretaceous)—Map unit includes the Paleocene and Upper Cretaceous Willow Creek Formation (Viele, 1960; Schmidt, 1972b) in southeast corner of map where only the lower part of the Willow Creek is present and where it consists of grayish-green, olive-drab, and light-gray mudstone and sandstone. Some coarse to very coarse grained beds of volcanic sandstone. The upper part of the St. Mary River consists of light- to dark-red, purplish-red, brown, gray, greenish-gray mudstone and sandstone, and some beds of volcanic sandstone and conglomerate. A thin bed of white ash-fall tuff occurs near middle part. The formation is as much as 790 m thick.

The upper part of the St. Mary River Formation, west of Augusta, is mostly grayish-green, sandy mudstone with moderate-light-red and purple interbeds. It contains numerous zones of dark-brown limestone nodules. Near Augusta, strata equivalent to the lower part of the St. Mary River are present and consist of grayish-green, olive-drab, and light-gray mudstone, sandy mudstone, and sandstone with some gray argillaceous limestone and carbonaceous shale. Sandstones are fine to medium grained and crossbedded. They are as much as 12 m thick. Thin argillaceous limestone beds as much as 0.3 m thick are locally present. A carbonaceous shale bed as much as 1.0 m thick is beneath a 1.0 m oyster bed near the base of the formation. Some reptile bone fragments and pelecypods are near the base. In the Augusta area the formation thickness is as much as 430 m.

Kh Horsethief Sandstone and Bearpaw- Horsethief transition unit (Upper Cretaceous)—Horsethief Sandstone is mostly gray to gray-brown, fine- to medium-grained crossbedded sandstone. The upper 6-12 m of the formation commonly contains lentils of titaniferous magnetite sandstone. Southeast of Augusta the Horsethief contains volcanic-rich sandstone and conglomerates (Viele and Harris, 1965).

The Horsethief is absent in the southeast part of the quadrangle where its position is marked by an Ostrea glabra bed (Viele, 1960); locally the sandstone contains pelecypods. The Horsethief is as much as 50 m thick.

The Bearpaw-Horsethief transition unit of Cobban (1955) beneath the Horsethief, consists of dark-gray mudstone interbedded with light-to medium-gray mudstone and fine- to medium-grained sandstone that is thin bedded in the lower part becoming thicker bedded in the upper part. Near Sun River a 0.3 m coal bed occurs about 6 m below the top. Thickness of the transition unit as much as 60 m.

Ku Upper and Lower Cretaceous rocks undivided, includes Two Medicine Formation, Virgelle Sandstone, Telegraph Creek Formation, Marias River Shale, and Blackleaf, Kootenai, and Mount Pablo Formations

Ktm Two Medicine Formation (Upper Cretaceous)—Gray-green and gray mudstone with minor sandstone in upper and middle parts with gray-green, olive-drab, and gray sandstone and mudstone in lower part. Upper and middle parts locally contain reddish-gray, red-brown, and purple interbeds of mudstone. The sandstones are fine to coarse grained and locally conglomeratic. Carbonaceous shale and locally a coal bed are present in the lower part. Petrified wood common about 30 m above base; vertebrate bones common in the upper 150 m. Pelecypods locally present at various horizons. Thickness about 670 m.

Ktv Volcanic-rich sedimentary rocks, flows, and tuffs—South of Augusta. The upper and middle parts are green, grayish-green, gray, brownish-gray, and maroon volcanic sandstone, mudstone, and conglomerate; brown, pink, and white ash-fall and ash-flow tuffs; and interbedded trachyte and latite flows (Viele, 1960; Viele and Harris, 1965; Schmidt and Strong, 1972; and Schmidt, 1972a, b, c). Lower 150 m is gray-green, olive-drab, and gray sandstone and mudstone. Thickness ranges from 640 m to possibly as much as 1,500 m.

Kvt Virgelle Sandstone and Telegraph Creek Formation (Upper Cretaceous)

Virgelle Sandstone—Consists of moderately thick, light-gray, fine-grained sandstone beds of which some are locally iron impregnated and crossbedded. At the top of the Virgelle, a titaniferous magnetite sandstone bed, as much as 6 m thick, forms a prominent rimrock south, west, and northwest of Choteau, as well as numerous other localities in the outcrop area. The Virgelle rarely contains pelecypods; wood fragments are locally in upper part. Thickness ranges from about 40 m to 60 m.

The Telegraph Creek Formation—A transitional unit between the underlying Marias River Shale and the overlying Virgelle Sandstone. Consists mainly of beds of gray mudstone and fine-grained sandstone. The sandstone beds are thinly

bedded in the lower part becoming thicker bedded in the upper part. Pelecypods and ammonites are common. Thickness ranges from about 90 m in the eastern outcrop to about 165 m in the western outcrop.

Km Marias River Shale (Upper Cretaceous)—Mostly a dark-gray mudstone that is divided into four members (listed in descending order), the Kevin, Ferdig, Cone, and Floweree, by Cobban and others (1959a, b, 1976). Total thickness ranges from 365 m to 395 m.

Kevin Member—Dark- gray mudstone with some very thin sandstone beds, numerous bentonite beds, and many light-gray calcareous concretions. Pelecypods and ammonites common. Ranges in thickness from 245 m to 305 m

Ferdig Member—Gray, noncalcareous siltstone and shale with many thin, iron-stained sandstone lenses, concretions of yellow-weathering limestone, red-weathering ferruginous dolostone, and some very thin bentonite beds. Contains abundant organic trails and burrows, but pelecypods and ammonites are rare. In the western outcrop, along the tributaries of the Sun River, the Ferdig is mostly sandstone (Mudge, 1972). Ranges in thickness from 50 m to 105 m.

Cone Member—Abundant, very thin, medium-gray calcareous siltstone and crystalline limestone beds in the upper part and dark-gray, noncalcareous shale in the lower part. Contains several bentonite beds throughout. Pelecypods and ammonites are common, especially in the upper part. The member ranges in thickness from 18 m to 30 m.

Floweree Member—Dark-gray, noncalcareous fissile to thin-bedded shale with medium-gray siltstone in lower part that locally contains lenses of chert-pebble conglomerate. Pelecypods and ammonites are rare. Thickness about 10 m.

KJ Lower Cretaceous and Jurassic rocks undivided

Blackleaf Formation (Lower Cretaceous)—Mostly sandstone and mudstone, and includes some fissile shale. Formation divided into three members (listed in descending order), Vaughn, Taft Hill, and Flood. The total thickness about 200 m in the eastern outcrop and 490 m in the western outcrop.

Vaughn Member—Nonmarine, light-gray, gray-green, and green tuffaceous and bentonitic mudstone and sandstone. Dark-gray carbonaceous mudstone locally in the upper part in the southeastern outcrop. The sandstone units are fine to coarse grained, locally crossbedded, and in places contain pebble and cobble conglomerate channel-fill deposits as much as 6 m thick (Mudge and Sheppard, 1968). The member contains wood and leaf fragments, and in the vicinity of Teton Pass contains coal and carbonaceous shale. Thickness from about 90 m in the eastern outcrop to about 150 m in the western outcrop.

Taft Hill Member—Marine, gray, thinly bedded, fine-grained sandstone units interbedded with dark-gray mudstone; the sandstone is locally crossbedded and ripple marked. In the northwest part of the quadrangle the upper part of the

member is replaced by nonmarine strata of Vaughn lithologies. Locally the Taft Hill contains numerous pelecypods. Thickness ranges from about 58 m in the southeast to about 183 m in the west.

Flood Member—Two marine, gray, sandstone units separated by as much as 150 m of dark-gray fissile shale. The sandstones are very fine grained, thin to moderately thick bedded, and locally crossbedded and ripple marked. Organic burrows and trails common. Thickness from about 45 m in the eastern outcrop to about 165 m thick in the western outcrop.

Kootenai Formation (Lower Cretaceous)—Consists of nonmarine, gray-green, and dark-reddish-brown mudstone interbedded with lenticular thin to thick sandstone units. Numerous heavily iron-stained, spheroidal nodules of dark-grayish-red sandy limestone are in the mudstone. The sandstone is fine to coarse grained, grayish-green, with chert and quartz grains and locally magnetite. Pebble and cobble conglomerate, as much as 15 m thick, fill narrow channels locally at the base of some sandstone units. In most places a distinctive hard, dense, brown coquinoid limestone containing abundant pelecypods and some vertebrate fragments at or near the top. Thickness ranges from 198 m to 245 m.

Mount Pablo Formation (Lower Cretaceous)—Nonmarine. Exposures widespread in the eastern mountains but locally absent in the adjacent foothills. Rests unconformably on the Morrison Formation. In the western drainages of the Sun River area was included as part of the western facies of the Morrison Formation by Mudge (1972). Ranges from a dominantly sandstone sequence with interbedded bright-reddish-brown mudstone to a dominantly reddish brown mudstone sequence with some sandstone. Dense, dark-gray to light-gray limestone beds as much as 9 m thick are present in the upper part of the formation. In many places, coarse sandstone and thin beds of conglomerate occur as channel-fill deposits. The sandstones are medium to very coarse grained, crossbedded, and contain wood fragments. Thickness about 60 m.

Morrison Formation (Upper Jurassic)—Nonmarine. A nearly complete section is present in the eastern and southern outcrop, but much of the formation was eroded prior to deposition of the Mount Pablo Formation in the western outcrop. Consists of tuffaceous, grayish-green, olive-green, and olive-gray claystone to siltstone with pink, maroon, purple, and yellowish-gray mudstones in the upper part. A thin, dark-gray carbonaceous shale present near the top in southeastern outcrop. Fine-grained clayey sandstone locally present. Abundant polished quartzite pebbles and limestone nodules characteristic of the Morrison locally. Cherty siderite lenses and nodules locally common about 35 m above the base of the formation. A thin, dark-gray-brown to gray limestone present in the lower part of the formation and locally in the middle part. Gastropods, pelecypods, plant fragments, ostracods, and vertebrate bones are sparse in the middle and lower parts of the formation. Thickness from 60 m to 82 m.

Swift Formation (Upper and Middle Jurassic)—Marine. Consists of thinly bedded gray to gray-brown fine-grained sandstone in the upper part and dark-gray to olive-drab mudstone with many thin beds of sandstone in the lower part. The upper beds are locally ripple marked and contain minute cross laminations and wood fragments. A thin glauconitic sandstone, with water-worn belemnites, present at the base of the formation. Formation rests unconformably on the Rierdon Formation everywhere except in the southeast corner of the map where it rests on the Sawtooth Formation. Thickness about 35 m.

Rierdon Formation (Middle Jurassic)—Marine. Widely distributed except in the southeast corner of the map area. Consists mostly of gray, calcareous mudstone with thin interbedded argillaceous limestone. Barite nodules common in the upper and middle parts. Pelecypods and ammonites common throughout. Thickness from 33 m to 60 m.

Sawtooth Formation (Middle Jurassic)—Marine. The upper member is gray-brown to yellowish-brown, calcareous, thin-bedded siltstone that contains pelecypods and ammonites. About 8 m thick. The middle member is dark-gray, silty to clayey fissile shale with local thin beds of fine-grained sandstone and conglomerate. Locally rests unconformably on Mississippian rocks. From 5 m to 77 m thick. The lower member is mostly thin bedded, fine-grained gray to yellowish-brown sandstone with a basal conglomerate of Mississippian rock fragments. Dark-gray, silty, thinly laminated shale locally interbedded in the sandstone. Pelecypods are locally abundant. Thickness of the lower member as much as 16 m.

Pz Paleozoic rocks. Includes part of or all of Mississippian, Devonian, and Cambrian sequences

Mu Upper and lower Mississippian rocks undivided—Mississippian rocks are the main cliff former in the eastern part of the mountains and are assigned to the Madison Group. The total thickness of the Mississippian rocks ranges from 275 m to 520 m. The Madison is divided into two formations, the Castle Reef Dolomite and the Allan Mountain Limestone, by Mudge, Sando, and Dutro (1962).

Castle Reef Dolomite (Upper and Lower Mississippian)—Divided into two members. Sun River Member at the top, which consists of thin to thick beds of medium to finely crystalline light-gray dolomite and locally some interbedded calcitic dolomite. Many beds contain thick lenses of encrinite and scattered brachiopods and corals. The Sun River is from less than 1 m to 137 m thick. The lower member is thick-bedded, fine to coarsely crystalline, light- to medium-gray dolomite, calcitic dolomite, dolomitic limestone, and limestone. The coarsely crystalline beds are encrinite and are more numerous in the northern and western outcrop. The lower member contains brachiopods and corals, locally abundant in the lower part. The lower member is 114 m to 145 m thick. Both members thin eastward, mainly as a result of pre-Jurassic erosion

Allan Mountain Limestone (Lower Mississippian)—Ranges in thickness from 63 m to 200 m, and contains three unnamed members. The upper member consists of gray, fine-grained, thin to thick beds of limestone, magnesian limestone, and dolomitic limestone. Nodules and lentils of gray- to gray-brown chert are common (Mudge, 1972). It has a large and varied fauna, mostly brachiopods and corals, and locally, lenses and beds of encrinite. Upper member 60 to 90 m thick. The middle member consists of dark-gray. fine-grained, thin to medium beds of limestone with some dolomitic limestone. Characteristically contains nodules and irregular-shaped to even-bedded lenses of dark-gray chert, of which some have a fibrous appearance (Mudge, 1972). Contains sparse brachiopods and corals (Mudge, Sando, and Dutro, 1962). The middle member about 45 m thick. The lower member mostly dark-gray, very thin bedded, argillaceous dolomitic limestone with many calcareous shale partings. Contains dense, gray, moderately thick limestone interbedded with dark-gray mudstone. The mudstone has abundant brachiopods and corals. Thickness of lower member 60 m to 89 m.

Du Upper and middle Devonian rocks undivided—Consists of limestone, dolomite, and some shale and mudstone; they range in thickness from about 300 m in the eastern outcrop to about 458 m in the western outcrop, and are divided into the Three Forks, Jefferson, and Maywood Formations.

Three Forks Formation (Upper Devonian)—The uppermost unit is a black shale bed of Early Mississippian age unnamed in this quadrangle but called the Sappington Member of the Three Forks elsewhere in Montana and is correlative to the Exshaw Shale in Alberta (Mudge, 1972). In most places it overlies thinly bedded, gray-brown to yellowish-gray limestone. The limestone commonly overlies an evaporite-solution breccia, but locally, in the Sun River area, overlies a thick bed of limestone and in one place a gray-green mudstone (Mudge, 1972). Fossils abound in the dark-gray shale and limestone beds. The rest of the Three Forks consists mostly of a pale-yellowish-brown to yellowish-gray evaporite-solution breccia consisting of angular fragments of dolomite and dolomitic limestone. Thickness from 15 m to 180 m.

Jefferson Formation (Upper Devonian)—Consists of two members: the Birdbear and a lower member. The Jefferson thickens eastward from about 190 m in the western outcrop to 247 m in the east. The Birdbear Member consists mostly of pale-yellowish-brown to brownish-gray, finely crystalline dolomite beds that pinch and swell. Brachiopods are commonly present. Ranges in thickness from 45 m to about 72 m. The lower member is mostly dolomite in the eastern outcrop, whereas it is mostly limestone in the western outcrop (Mudge, 1972). Consists of distinctive gray-brown beds (mostly less than 1/2 m thick) that characteristically have a fetid odor on the broken surface. Many beds have a sucrosic texture. The lower part commonly contains one or more thin beds of evaporite-solution breccia. Dark-gray chert lenses common in the lower part in

the eastern outcrop. Corals, brachiopods, and stromatoporoids common throughout and Amphipora biostromes are widespread in the upper part. Thickness from 128 m to 198 m.

Maywood Formation (Upper and Middle Devonian)—Contains an upper limestone member and a lower mudstone member. The upper member is mainly dark grayish-brown and yellowish-gray, thinly bedded, finely crystalline limestone and dolomitic limestone that thickens eastward from about 21 m in the west to 48 m in the east. Contains brachiopods and corals. The lower member is mostly greenish gray dolomitic mudstone that in the western outcrops is interbedded with maroon mudstone. Contains thin beds of crystalline yellowish-gray to olive-gray dolomite and dolomitic limestone. A widespread dolomite with some breccia present in the middle part of the member. Charophytes and conodonts are locally present in one of the dolomite beds. The lower member ranges in thickness from about 8 m in the eastern outcrop to 63 m in the western outcrop.

Cu Cambrian rocks undivided—Complete sections of these rocks are only in the western outcrop. Deiss (1939) divided these rocks into nine formations: Devils Glen Dolomite (top), Switchback Shale, Steamboat Limestone, Pentagon Shale, Pagoda Limestone, Dearborn Limestone, Damnation Limestone, Gordon Shale, and Flathead Sandstone (bottom). The Pentagon Shale occurs only in the vicinity of Pentagon Mountain where Deiss (1939) noted it to extend about 25 km to the south and about 7 km north of the mountain. The Devils Glen, Switchback, and Steamboat are in thrust blocks in the eastern outcrops. The limestone formations contain considerable mudstone in the east, but they are mostly limestone in the west. All formations locally contain trilobites and some brachiopods. The Cambrian rocks thin northwestward from 681 m near the Dearborn River to 439 m at Pagoda Mountain (Deiss, 1939).

Devils Glen Dolomite (Upper Cambrian)—A distinctive, thick-bedded, light-gray, finely to very finely crystalline dolomite. Thickness from 54 m to 172 m (Deiss, 1939).

Switchback Shale (Upper and Middle Cambrian)—Mostly noncalcareous, greenish-gray, thinly laminated clay shale with local thin interbeds of dolomite, limestone, sandstone, and conglomerate. Thickness from 21 m to 92 m.

Steamboat Limestone (Middle Cambrian)—Differs in lithology between western and eastern outcrops. In the west consists of a lower shaly mudstone interval and a much thicker upper limestone interval (Deiss, 1939). In the eastern exposures is about equal parts of alternating sequences of limestone and calcareous shale. The carbonate units in both areas consist mostly of nodular, hard, dark-yellowish-brown, thinly bedded limestone and dolomite with nodules and lentils of dark-yellowish-orange siltstone. The mudstone units are mainly grayish-green noncalcareous shale with interbeds of calcareous siltstone and claystone. Trilobites, locally abundant, and some brachiopods occur in limestone lenses in

the shales and locally near the top of the limestone units. Thickness from 65 m to 80 m.

Pentagon Shale (Middle Cambrian)—A clastic wedge that consists of very fossiliferous, calcareous, gray to tan-gray, thick-bedded platy shale that contains some platy, blue-gray argillaceous limestone in the upper part (Deiss, 1939). Thickness ranges from less than 1 m to 88 m (Deiss, 1939).

Pagoda Limestone (Middle Cambrian)—Forms prominent light-gray cliffs in the Cambrian sequence. The upper part consists of yellowish-gray to light-yellowish-brown, thin- to thick-bedded dolomitic limestone and some dolomite overlying very thin-bedded limestone. The lower part consists of grayish-green, thinly laminated to nodular clay shale with some gray-brown limestone and minor sandstone. An intraformational conglomerate locally present in the middle and lower parts. Trilobites and brachiopods locally numerous in the shale (Deiss, 1939). Formation thickens to the south and west, and ranges in thickness from 28 m to about 120 m.

Dearborn Limestone (Middle Cambrian)—Composed of an upper thick limestone unit and a lower thin shale unit. The limestone unit is finely crystalline, yellowish-brown to gray, thin to thick bedded and irregularly bedded. The lower unit consists of gray to gray-green clayey shale with some sandy shale and thin interbedded limestone. Trilobites present in the lower part of the shale unit. Thickness from 67 m to 106 m.

Damnation Limestone (Middle Cambrian)—Consists of medium- to dark-gray, thin- to thick-bedded, finely crystalline dolomitic limestone and limestone with laminae of grayish-orange to yellowish-gray siltstone that thicken and thin. Locally they are oolitic and contain trilobites, brachiopods, and organic trails and burrows. Thickness from 30 m to 68 m.

Gordon Shale (Middle Cambrian)—Mainly a dark-gray to gray-brown, very thinly laminated shale with a greenish tint and locally maroonish-gray beds. Contains many thin beds of sandstone and some beds of limestone, especially in the middle and upper parts. In places the limestones contain glauconite, algal structures, limestone chips, grains of quartz, and fossil fragments. The upper part contains numerous fossils (Deiss, 1939), whereas the lower beds locally contain organic trails and burrows, some by trilobites. Thickness from 42 m to 90 m.

Flathead Sandstone (Middle Cambrian)—Consists of thin- to thick-bedded and crossbedded, noncalcareous yellowish-gray, poorly sorted, poorly indurated, fine- to coarse-grained quartzose sandstone with scattered quartz pebbles. Beds are characteristically speckled by disseminated hematite. Interbeds of gray, purple, or maroon mudstone locally present. Thickness from 13 m to 35 m.

PROTEROZOIC Y STRATIFIED ROCKS

The Proterozoic stratified rocks in the quadrangle are assigned to the Belt Supergroup and consist of quartzite, siltite, argillite, limestone, and dolomite that are metamorphosed to the chlorite subfacie, The Belt Supergroup is divided upper, middle, and lower parts. The upper part is the Missoula Group, which consists mostly of fine-grained clastic rocks and minor limestone and dolomite above the Helena Formation. The middle part is the Helena Formation, which consists mostly of limestone and dolomite. The lower part, the Ravalli Group, contains mostly siltite and argillite with minor quartzite, limestone, and dolomite. Thickness of the Belt Supergroup in the quadrangle ranges from 2,000 m in the eastern part to more than 10,000 m in the western part.

Ygr Garnet Range Foromation (Proterozoic Y)—Consists of pale-olive to medium- gray and moderate brown poorly sorted very fine to fine-grained, micaceous, thin even beds of sandstone and siltstone. Locally they are speckled by hematite, crossbedded and ripple marked. The formation varies in thickness due to pre-Middle Cambrian erosion and ranges from less than 1 m to 490 m, attaining its greatest thickness in the southern outcrops.

Ybe McNamara Formation, Bonner Quartzite, and Mount Shields, Shepard, Snowslip, Helena, Empire, and Spokane formations (Proterozoic Y)

Ym McNamara Formation (Proterozoic Y)—In the central and southern parts of the area the McNamara is divisible into two unnamed members, an upper dominantly reddish-brown quartzite and a lower dominantly grayish-green siltite (Somers, 1966; Mudge and Earhart, 1978). Quartzite in the upper member is interbedded with siltite and minor argillite. Most of the unit is thin-bedded, fine-grained, micaceous, minutely crossbedded, and locally ripple marked. The lower member contains thin beds of argillite and fine- to medium-grained quartzite and locally some reddish-gray siltite. Ripple marks, minute crossbedding, and load casts are common. The upper part of the lower member contains thin beds of glauconitic sandstone, some barite nodules, and vuggy reddish chalcedony, particularly in the eastern outcrop area (Mudge, 1972; Mudge and Earhart, 1978). In the northern part of the area, the formation thickens and is dominantly grayish-green siltite. The formation varies in thickness, due in part to pre-Middle Cambrian erosion, and ranges from 47 m to 1,650 m. Where overlain by the Garnet Range Formation its minimum thickness is 640 m; it thickens northward.

Ymi Bonner Quartzite, and Mount Shields, Shepard, Snowslip formations, undivided (Proterozoic Y)—Mapped only in the upper reaches of Smith and Elk Creeks.

Yb Bonner Quartzite (Proterozoic Y)—Consists mostly of pink, pale-red, and pinkish-gray, fine- to medium-grained, poorly sorted beds of quartzite that range in thickness from 31 cm to 76 cm. The quartzite is mostly feldspathic and locally includes fragments of red argillite. Many beds are crossbedded and ripple marked. Thickness ranges from 213 m to 580 m.

Yms Mount Shields Formation (Proterozoic Y)—Mostly bright reddish-brown, thinly laminated, micaceous siltite, argillite, and thin-to thick-bedded quartzite. Sedimentary features include minute cross-laminations, ripple marks, mud-crack fillings, and mud chips. A grayish-green siltite unit with local interbedded dark-gray fissile shale widespread in the upper part of the formation. Salt-crystal casts widespread in the upper part of the formation, beneath the grayish-green unit. The quartzite beds are mostly fine to medium grained and more common in the middle and lower parts of the formation. A thick (155 m to 305 m) quartzite unit is present in the upper-middle part of the formation in the southern outcrop. It contains poorly sorted, fine- to coarse-grained, pinkish-gray to reddish-brown quartzite beds less than 1 m thick that are separated by thin beds of reddish-brown siltite and argillite. The color, grain size, and sedimentary features of the quartzite beds are similar to those in the Bonner Quartzite. The lower part of the formation in the eastern outcrop commonly contains thin beds of glauconitic quartzite. In the central and northern parts of the area the formation is more argillitic and contains beds of stromatolitic and oolitic limestone. The formation thickens south and west, from 555 m in the eastern outcrop to 2,180 m in the west at Swan Range and to 1,860 m in the south.

Ysh Shepard Formation (Proterozoic Y)—Consists mostly of greenish-gray to grayish-yellow micaceous siltite and some silty limestone and argillite. Beds of maroon siltite and argillite widespread in the middle part and locally in the upper part. Thin glauconitic quartzite lentils widespread in the upper part of the formation in the eastern outcrop, but sparse elsewhere. Ripple marks, minute cross lamination, load casts, and mud cracks also common in the eastern outcrop. An edgewise conglomerate present near the base of the formation in the east, but elsewhere a stromatolitic limestone bed occurs at the same horizon. Other beds of stromatolitic limestone also present in the lower part of the formation in the Mission Range (Harrison and others, 1969). The formation thickens westward and southward, from 249 m in the eastern outcrop to about 900 m in the west in the Swan Range and about 715 m in the south.

Ysn Snowslip Formation (Proterozoic Y)—Consists of pale-red to reddish-brown beds and interbedded greenish-gray beds of argillite and siltite with some thin beds of very fine to fine-grained quartzite. Thin beds of stromatolitic and oolitic limestone and flat pebble conglomerate locally occur at various horizons.

Crossbedded, minute laminae, ripple marks, and mud cracks common features; raindrop impressions mudchip conglomerates less common. Thin beds of poorly sorted, fine- to coarse-grained quartzite and gritstone common near the lower contact. The formation thickens west and south, from about 215 m in the eastern outcrop to 1, 660 m in the Swan Range and 1,100 m in the southern part of the area.

Yh Helena Formation (Proterozoic Y)—ln most places the Helena is divisible into three units. The upper unit consists of beds of limestone interbedded with dolomite, siltite, and argillite. Beds of stromatolites, oolites, and edgewise conglomerates widespread. The middle unit, comprising most of the formation, consists of light- to medium-gray, thin to thick-bedded silty limestone, dolomite, and calcitic dolomite that weathers to a yellowish gray to grayish orange. Commonly, vertical ribbons, blobs, horizontal mats, lenses, and pods differentially weather to form crenulating patterns ("molar tooth structure," O'Connor, 1967). Stromatolites, oolites, and edgewise conglomerates locally present at various horizons, especially in the eastern outcrop. The lower unit consists mostly of calcareous or dolomitic siltite with some beds of dolomite and quartzite. The siltite is gray, greenish-gray, and locally dark red near the lower contact. The quartzite that occurs at the base is light gray, thinly bedded, calcareous, medium grained, and poorly sorted. The Helena thickens westward and southward, from about 205 m in the central part of the eastern outcrop to about 3,000 m in the Mission Range (Harrison and others, 1969) to 1,662 m in the south (Mudge and others, 1974).

Yes Spokane and Empire Formations undivided (Proterozoic Y)—Undivided only in the eastern and part of the southern outcrop area. In those areas the unit is pale-red, maroon, green, and gray siliceous argillite and siltite, with minor thin beds of poorly sorted, fine-grained quartzite. Locally in the eastern outcrop also contains some thin beds of dolomite, edgewise conglomerate, and stromatolite beds.

Ye Empire Formation (Proterozoic Y)—A transitional unit between the Helena and Spokane Formations. Mostly greenish gray argillite and siltite with interbeds of quartzite, dolomite, and locally stromatolitic and oolitic carbonate rock. The quartzites are poorly sorted, ranging from very fine to medium grained, and locally carbonate cemented. The amount of carbonate appears to increase upward. Red to purple beds of predominantly argillite occur in the lower part of the formation. The formation varies in thickness from less than 1 m to as much as 610 m (Mudge and others, 1974, 1978).

Ys Spokane Formation (Proterozoic Y)—Mostly pale-purplish-red and grayish-red siltite and argillite interbedded with lithologically similar greenish-gray beds. The

southeastern and northwestern outcrops contain light-gray, very fine to medium-grained, thin beds of quartzite that locally contain minute crossbeds and ripple marks. The formation as much as 1,500 m thick in the Swan Range (Johns, 1970) and as much as 915 m thick in the southeast (Schmidt and Strong, 1972).

Yg Greyson Formation (Proterozoic Y)—The oldest unit exposed in and near the map area; therefore, its base is not exposed. Consists of light-gray to greenish-gray, thinly bedded siltite with some quartzite, grading down into dark-gray, greenish-gray, very thinly laminated argillite and siltite in the lower part. Its sedimentary features include ripple marks, mudcracks, and locally salt crystal casts (Schmidt and Strong, 1972). Thickness of the formation is as much as 762 m (Schmidt and Strong, 1972)

IGNEOUS ROCKS, YOUNGER THAN EARLY TERTIARY THRUST FAULTING IN THE MONTANA DISTURBED BELT

Tb Basalt (Pliocene?)—Occurs mostly as dark-gray to gray-brown, finely porphyritic flows with numerous calcite- and zeolite-filled cavities. Locally weathers into spheroidal boulders and overlies Tertiary lakebed deposits. Present only in the Keep Cool Lakes area on the southern border of map area

Td Dacite (Miocene? and Oligocene)—Volcanic neck or plug and sills, gray to light-gray, aphanitic groundmass of greenish-gray feldspar with phenocrysts of light-gray feldspar, hornblende, and biotite. Present only at and near Haystack Butte in southeastern part of map area.

Tm Hornblende monzonite (Eocene?)—Light-gray, fine-grained, equigranular dikes and sills composed of andesine, sanidine, hornblende, augite, biotite, magnetite, and apatite. Hornblende needles, 3-4 mm long, characterize the rock (Schmidt, 1972b, c; Schmidt and Strong, 1972). Dated as 46.3 m.y. by the K-Ar method (Schmidt, 1978). Widespread in southeast corner of map area.

Tmp Monzonite porphyry (Eocene?)—Stocks, dikes, and sills, of light-gray, abundant, 1-cm and larger phenocrysts of orthoclase that weather out as euhedral crystals. Dated at 58.3 m.y. by the K-Ar method (Mehnert and Schmidt, 1971; Schmidt, 1978). Present only in southeast corner of map area.

Ta Biotite trachyandesite and andesite (Paleocene?)—Dikes, sills, and irregular shaped bodies. Includes trachybasalt and bioite trachybasalt of Schmidt (1972b, c, 1978). Dark-gray, aphanitic groundmass with hornblende and some biotite phenocrysts, weathers brown. Present only in the southeast corner of map area.

IGNEOUS ROCKS OLDER THAN EARLY TERTIARY THRUST FAULTING IN THE MONTANA DISTURBED BELT

Tva Adel Mountain Volcanics of Lyons (1944) (Paleocene?)—Volcanic and volcanic-sedimentary rocks. Trachyandesite and trachybasalt flows (Schmidt, 1972a), volcanic conglomerate, breccia, and lacustrine deposits of volcanic sandstone, siltstone, and mudstone (Schmidt, 1972a, 1978). Present only in southeast corner of map area.

Tki Trachyandesite (Paleocene or Upper Cretaceous)—Sills, dark grayish brown, aphanitic groundmass of feldspar with phenocrysts of plagioclase, potassium feldspar, pyroxene, and quartz (Mudge, 1972). Widespread near the North Fork Sun River.

TKr Rhyolite (Paleocene or Upper Cretaceous)—Dikes and sills, light-gray to white-, finely porphyritic with abundant 2-3 mm phenocrysts of quartz and oligoclase (Schmidt, 1972c, 1978). Present only in southeast corner of the map area.

TKp Quartz monzonite porphyry (Paleocene or Upper Cretaceous)—Sills, light-grayish-orange; coarsely porphyritic with abundant 1 cm and larger phenocrysts of potassium feldspar and oligoclase-andesine in a fine-grained groundmass (Schmidt, 1972c, 1978).

Kl Latite (Cretaceous)—Sill, gray, grayish-purple; massive and porphyritic with abundant phenocrysts of labraclorite in an aphanitic groundmass (Schmidt, 1972c, 1978). Present only in southeast corner of map area.

Ks Diorite sills (Cretaceous?)—includes rhyodacite porphyry and diorite as mapped by Schmidt and Strong (1972) and Schmidt (1978). The rhyodacite is greenish gray with phenocrysts of oligoclase and hornblende mainly in a groundmass of quartz and feldspar. The diorite is greenish gray, fine grained, and equigranular (Schmidt and Strong, 1972). Present only in southeast corner of map area.

Zd Diorite sills and local dikes (Proterozoic Z)—Mostly diorite and quartz diorite, locally minor diorite-gabbro and monzonite. Dark gray, weathers grayish brown. Dated at 750±25 m.y. by K-Ar method (J. D. Obradovich, oral commun., 1966). Widespread throughout map area.

Ydi Andesite, basaltic andesite, and dacite (Proterozoic Y)—Thin sills, grayish-green; amphibole, biotite, and feldspar phenocrysts in aphanitic groundmass of plagioclase and ferromagnesian minerals. Probably equivalent in age (1,075 m.y.) to the Purcell Lava of the Belt Supergroup in Glacier National Park. Present in southern part of map area near and southeast of Red Mountain

Data Sources, Processing, and Accuracy

The Choteau geologic map database was initially prepared by Jeffery T. Silkwood (U.S. Forest Service) from the geologic map by Mudge and others (1982). These preliminary digital files were transferred to the U.S. Geological Survey (USGS) in 1999. Robert J. Miller (USGS) merged the geology (lines and polygons) and structure (lines) files into a single topological ArcInfo dataset. Steven R. Munts (contractor) digitized additional structural features (folds) from Mudge and others (1982). The digital files were then augmented with an interim geologic map data model (data base), further attributed and edited, and then plotted and compared to the published geologic map to check for digitizing and attribute errors. All processing by the U.S. Geological Survey was done in Arc/Info version 7.2.1 installed on a Unix-based Sun Ultra workstation.

The overall accuracy (with respect to the location of lines and points) of the digital geologic map (see figs. 2 and 3 for page-size versions) is probably no better than +/- 55 meters. This digital database is not meant to be used or displayed at any scale larger than 1:250,000 (for example, 1:100,000 or 1:24,000).

GIS Documentation

The digital geologic map of the Choteau 1:250,000 quadrangle includes a geologic (linear features) arc attribute table, CHOT250K.AAT, that relates to the CHOT250K.CON, CHOT250K.LGU CHOT250K.ST2, and CHOT250K.REF files; a rock (areal features) unit polygon attribute table, CHOT250K.PAT, that relates to the CHOT250K.RU and CHOT250K.REF files; and a plunging fold direction point attribute table, CHOT250P.PAT, that relates to CHOT250P.SYM and CHOT250K.REF files (see fig. 4). These data files are described below.

Figure 2. Explanation for the Simplified Digital Geologic Map of the Choteau 1:250,000 quadrangle, Montana

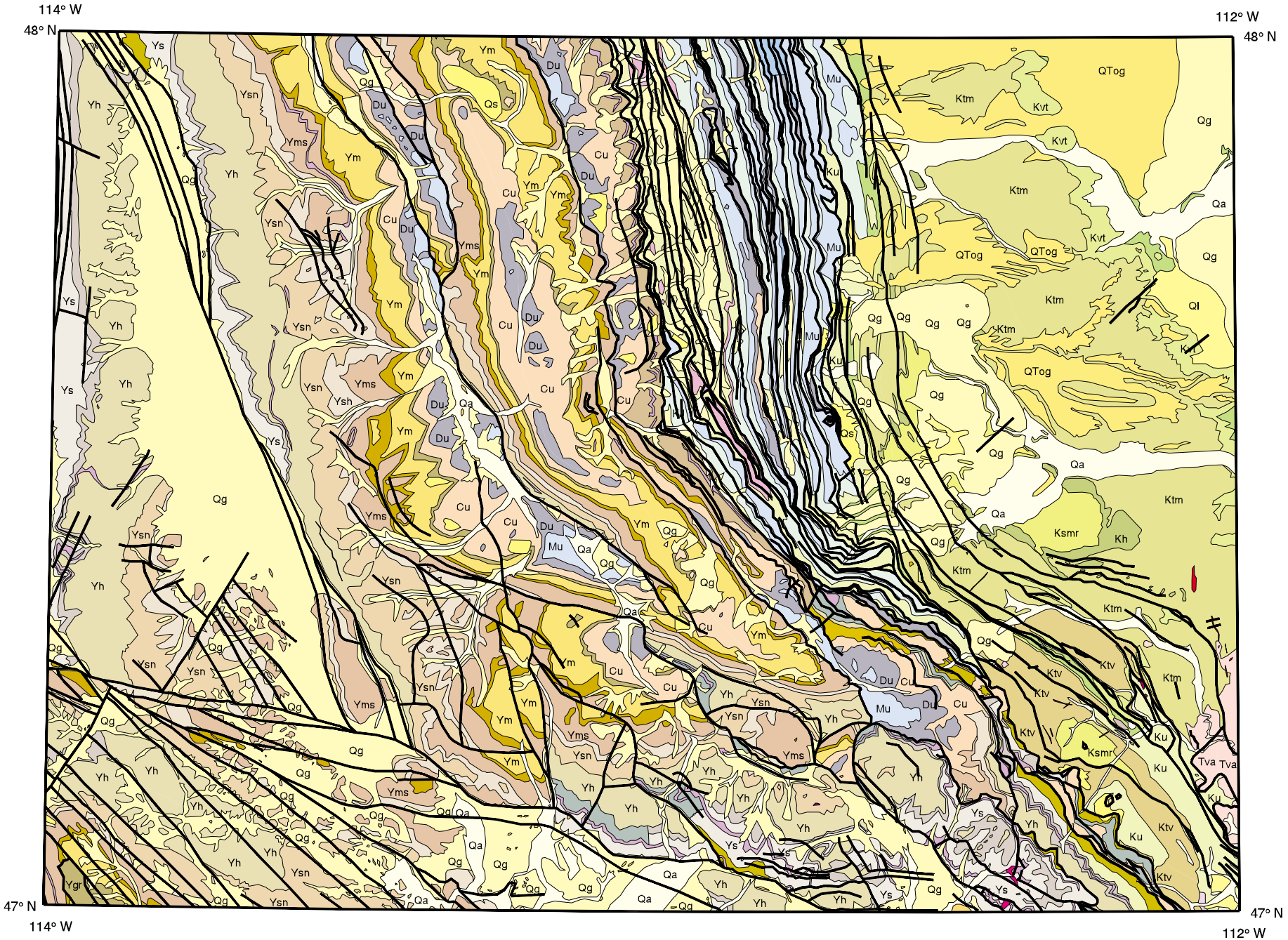

Figure 3. Simplified Digital Geologic Map of the Choteau 1:250,000 quadrangle, Montana

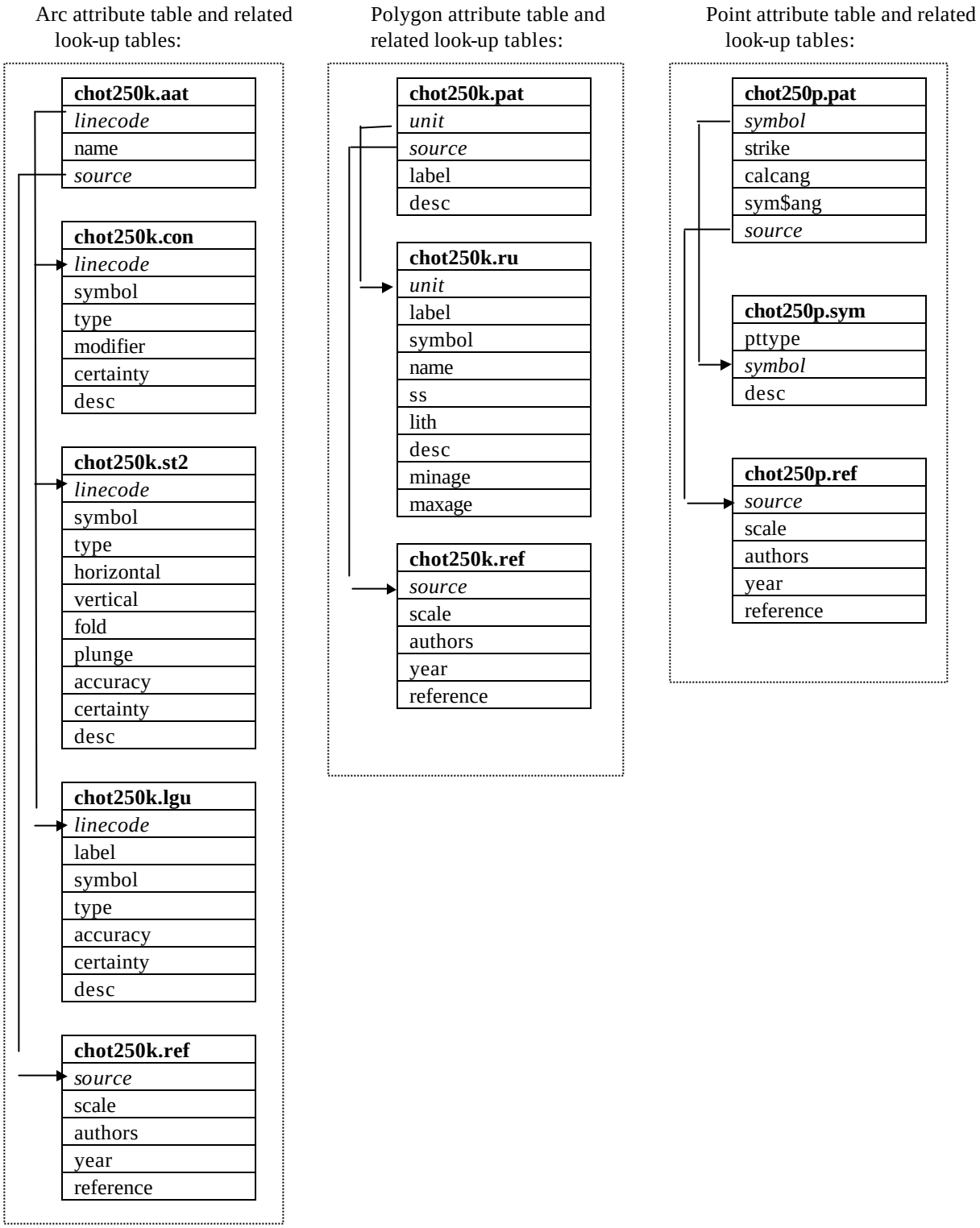

Figure 4: Relationships between feature attribute tables and look-up tables

Linear Features

Descriptions of the items identifying linear features such as contacts, boundaries (for example, lines of latitude and longitude, state boundaries) and structures in the arc (or line) attribute table, CHOT250K.AAT, are as follows:

CHOT250K.AAT			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
linecode	integer	3	Numeric code used to identify type of linear feature. Linecodes < 100 are used for contacts and boundaries which are described in the CHOT250K.CON file. Linecodes > 100 and < 600 represent structural features which are described in the CHOT250K.ST2 file.
name	character	30	Name given to structural feature.
source	integer	4	Numeric code used to identify the data source for the linear feature. Complete references for the sources are listed in the CHOT250K.REF file.

Attribute descriptions for items in the contact (and boundary) look-table, CHOT250K.CON [for use with the CARTO.LIN and GEOL_SFO.LIN linesets], are as follows:

CHOT250K.CON			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
linecode	integer	3	Numeric code (a value < 100) used to identify type of contact or boundary. (This item also occurs in CHOT250K.AAT.)
symbol	integer	3	Line symbol number used by Arc/Info to plot lines. Symbol numbers refer to the **CARTO.LIN lineset** for linecodes gt 42 and lt 100 and to the **GEOL_SFO.LIN lineset** for linecodes gt 0 and lt 43.
type	character	10	Major type of line, for example, contact, state boundaries, lines of latitude and longitude used for neatlines.
modifier	character	20	Line type modifier, i.e., approximate, concealed, gradational. No entry implies 'known.'
certainty	character	15	Degree of certainty of contact or boundary, i.e., inferred, uncertain. No entry implies 'certain.'
desc	character	100	Written description or explanation of contact or boundary.

Attribute descriptions for items in the structure look-up table, CHOT250K.ST2 [for use with the GEOL_SFO.LIN lineset], are as follows:

CHOT250K.ST2			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
linecode	integer	3	Numeric code (a value > 100 and < 600) used to identify type of structural feature. (This item also occurs in CHOT250K.AAT.)
symbol	integer	3	Line symbol number used by Arc/Info to plot arc (line). Symbol numbers refer to the **GEOL_SFO.LIN lineset**.
type	character	10	Major type of structure, i.e., fault, fracture, fold, other.
horizontal	character	20	Type of horizontal fault movement, for example, left-lateral, right-lateral. No entry implies 'unknown.'
vertical	character	20	Type of vertical fault movement, for example, normal. No entry implies 'unknown.'
fold	character	15	Type of fold, for example, anticline, syncline.
plunge	character	15	Type of plunge on fold, i.e., horizontal, plunging, plunging in, plunging out.
accuracy	character	15	Line type modifier indicating degree of accuracy, i.e., approximately located, concealed, gradational. No entry implies 'known.'
certainty	character	15	Degree of certainty of contact or boundary, i.e., inferred, uncertain. No entry implies 'certain.'
desc	character	100	Written description or explanation of structural feature.

Attribute descriptions for items in the linear geologic units (for example, veins, dikes and rock units that could only be mapped as linear features at a scale of 1:250,000) look-up table, CHOT250K.LGU, are as follows:

CHOT250K.LGU			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
linecode	integer	3	Numeric code (a value > 800) used to identify type of linear geologic unit. (This item also occurs in CHOT250K.AAT.)
label	character	10	Map label used in the map proper to identify rock unit.
symbol	integer	3	Line symbol number used by Arc/Info to plot linear geologic unit. Symbol numbers refer to **GEOL_SFO.LIN lineset** .
type	character	20	Major type of linear geologic unit, for example, dike, formation.
accuracy	character	15	Line type modifier indicating degree of accuracy, i.e., approximate, concealed, gradational. No entry implies 'known.'
certainty	character	15	Degree of line type certainty, i.e., inferred, uncertain. No entry implies 'certain.'
desc	character	100	Written description or explanation of linear geologic unit.

Areal Features

Descriptions of the items identifying geologic units in the polygon attribute table, CHOT250K.PAT, are as follows:

CHOT250K.PAT			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
unit	integer	4	Numeric code used to identify the rock unit, which is described in the CHOT250K.RU look-up table. (This item also occurs in CHOT250K.RU.)
source	integer	4	Numeric code used to identify the data source for the rock unit. Complete references for the sources are listed in the CHOT250K.REF file.
label	character	10	Rock unit label (abbreviation) used to label unit on map. (This item was joined from the CHOT250K.RU look-up table.)
desc	character	250	Formal or informal unit name. (This item was joined from the CHOT250K.RU look-up table.)

Attribute descriptions for items in the lithology (rock unit) look-table, CHOT250K.RU (for use with the WPGCMYK.SHD shadeset), are as follows:

CHOT250K.RU			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
unit	integer	4	Numeric code used to identify rock unit. (This item also occurs in CHOT250K.PAT.)
label	character	10	Rock unit label (abbreviation) used to label unit on map.
symbol	integer	3	Shadeset symbol number used by Arc/Info to plot a filled/shaded polygon. The symbol numbers used in this file refer to the **WPGCMYK.SHD shadeset**.
name	character	7	The prefix portion of the rock unit label that does not include subscripts. (If subscripting is not used in the original unit label, then the 'name' entry is the same as the 'label' entry.)
ss	character	3	The suffix portion of the geologic unit label that includes subscripts.
lith	character	20	Major type of lithostratigraphic unit, i.e., unconsolidated sediments, sedimentary rocks, metasedimentary rocks, intrusive rocks, extrusive rocks, metamorphic rocks, water, ice.
desc	character	100	Formal or informal unit name
minage	character	7	Minimum stratigraphic age of lithologic unit, i.e., CRET, TERT, PCY.
maxage	character	7	Maximum stratigraphic age of lithologic unit

Point Features

Descriptions of the items identifying fold plunge map symbols are given in the point attribute table, CHOT250P.PAT, which is defined as follows:

CHOT250P.PAT			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
symbol	integer	3	Marker symbol number used by Arc/Info to identify type of geologic map symbol. Symbol numbers refer to the **GEOSCAMP2.MRK markerset** (Matti and others, 1997). (This item also occurs in the CHOT250P.SYM file.)
strike	integer	3	Strike of fold plunge. Strike is an azimuthal angle (measured in degrees from 0 to 360 in a clockwise direction from North).
calcang	integer	4	An interim value used to calculate sym$angle. The various structural map symbols in the GEOSCAMP2.MRK markerset (Matti and others, 1997) had to be rotated by different amounts to achieve their proper map orientation. For the strike and dip symbols, calcang = strike – 240.
sym$angle	integer	4	The angle used to complete the mathematical rotation of the structural map symbol to its proper orientation on the map. This value is the $angle pseudoitem value for the point.
source	integer	4	Numeric code used to identify the data source for the structural map symbol. Complete references for the sources are listed in the CHOT250K.REF file.

Attribute descriptions for items in the geologic map symbols look-up table, CHOT250P.SYM, [for use with the GEOSCAMP2.MRK markerset (Matti and others, 1997)], are as follows:

CHOT250P.SYM			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
pttype	character	32	Type of point symbol, for example, strike of plunge of fold . (This item also occurs in the CHOT250P.PAT file.)
symbol	integer	3	Marker symbol number used by Arc/Info to identify type of structural map symbol. Symbol numbers refer to the **GEOSCAMP2.MRK markerset** (Matti and others, 1997).
desc	character	250	Written description or explanation of map symbol.

Source Attributes

Descriptive source or reference information for the CHOT250K and CHOT250P ArcInfo datasets is stored in the CHOT250K.REF and CHOT250P.REF files, respectively. Attribute descriptions for items in the CHOT250K.REF and CHOT250P.REF files are as follows:

CHOT250K.REF/CHOT250P.REF			
ITEM NAME	ITEM TYPE	ITEM LENGTH	ATTRIBUTE DESCRIPTION
source	integer	4	Numeric code used to identify the data source. (This item also occurs in the CHOT250K.AAT, CHOT250K.PAT, and CHOT250P.PAT files.)
scale	integer	8	Scale of source map. (This value is the denominator of the proportional fraction that identifies the scale of the map that was digitized or scanned to produce the digital map.)
authors	character	200	Author(s) or compiler(s) of source map entered as last name, first name or initial, and middle initial.
year	integer	4	Source (map) publication date
reference	character	250	Remainder of reference in USGS reference format.

Obtaining Digital Data

The complete digital version of the geologic map is available in Arc/Info interchange format with associated data files. These data and map images are maintained in a Transverse Mercator map projection:

Projection:	TRANSVERSE
Units:	METERS
Spheroid:	CLARKE1866
Datum:	NAD27
Parameters:	
scale factor at central meridian	1.00000000
longitude of central meridian	-113 0 0.00
latitude of origin	0 0 0.000
false easting (meters)	0.00000
false northing (meters)	0.00000

To obtain copies of the digital data, do one of the following:

1. Download the digital files from the USGS public access World Wide Web site on the Internet:
   URL = http://geopubs.wr.usgs.gov/i-map/i-1300/

   or

2. Anonymous FTP from **geopubs.wr.usgs.gov,** in the directory
   pub/i-map/i-1300

The Internet sites contain the digital geologic map of the Choteau 1:250,000 quadrangle both in an ArcInfo interchange-format file (chot250k.e00) and as HPGL2 (chot250k) plot files and PDF (chot-map.pdf) of the map area, as well as the associated data files and Arc/Info macro programs which are used to plot the map at a scale of 1:250,000.

To manipulate these data in a geographic information system (GIS), you must have a GIS that is capable of reading Arc/Info interchange-format files.

Obtaining Paper Maps

Paper copies of the digital geologic map are not available from the USGS. However, with access to the Internet and access to a large-format color plotter that can interpret either HPGL2 (Hewlett-Packard Graphics Language), or PDF (portable document format) files, a 1:250,000-scale paper copy of the map can be made, as follows:

1. Download the digital version of the map, **chot250k.hp** or **chot-map.pdf,** from the USGS public access World Wide Web site on the Internet using the
URL = http://geopubs.wr.usgs.gov/i-map/i1300/
or
2. Anonymous FTP the plot file, **chot250k.hp** or **chot-map.pdf,** from: **geopubs.wr.usgs.gov,** in the directory:
pub/open-file/i-map/i1300
3. This file can be plotted by any large-format color plotter that can interpret HPGL2 or PDF files. The finished plot is about 30 inches by 40 inches.

Paper copies of the map can also be created by obtaining the digital file as described above and then creating a plot file in a GIS.

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Appendix A - List of digital files in the Choteau GIS

—Use the 'importfile.aml' to IMPORT all of the *.E00 files for use in ArcInfo.
—Use the ArcInfo 'DRAW' command to plot the *.GRA file to your screen. (Make sure the display is set with the ArcInfo 'DISPLAY' command.)
—Use the ArcInfo 'HPGL2' command to create a HPGL2 file from the *.GRA file.
—Use the UNIX 'lpr -P<plotter_name> chot250k.hp' command to send the chot250k.hp file to a large-format color plotter that can interpret Hewlett-Packard Graphics Language.
—To re-create the *.GRA file, open the ArcPlot module, enter 'display 1040', enter a new filename for the graphics file, enter '&run chot250k'.

Primary ArcInfo interchange-format (*.e00) and metadata files for the digital geology:

- chot250k.e00 – line and poly GIS
- chot250p.e00 – point GIS
- chot250k.met - metadata

Arc/Info graphics (*.gra), HPGL2 (*.hp), encapsulated postscript (*.eps) and portable document format (*.pdf) files for the geologic map sheet:

- chot250k.gra /.hp/.eps
- chot-map.pdf

Additional ArcInfo interchange-format files (*.e00) necessary to re-create the geologic map sheet:

- wpgcmyk.shd.e00 - shadeset
- c250box.e00 - exterior boundary of the Choteau quadrangle.
- fnt037.e00 – font 37
- geol_sfo.lin.e00 - lineset
- plotter.lin.e00 – lineset
- plotter.mrk.e00 – marker set
- geoscamp2.mrk.e00 – marker set

AML (*.aml), graphics (*.gra), key (*.key), and text files (*.dat, *.prj, *.txt) necessary to re-create the geologic map sheet:

- chot250k.aml - program that creates a graphics file of the geologic map of the Choteau quadrangle
- importfile.aml – program to automatically import ArcInfo interchange format (*.e00) files
- scale2a.aml – program to plot scale bar
- indexmap.gra - index map graphic file
- usgslogo.gra – USGS visual identity
- chotlin2.key - lineset symbol values and descriptive text.
- chotpoly.key - shadeset symbol values and descriptive text for geologic map units
- cal.dat – plotter calibration data file
- geo.prj - real-world (geographic) coordinates - for use in adding latitude and longitude notation around the margins of the quadrangle
- trans.prj - Transverse Mercator map projection - for use in adding latitude and longitude notation around the margins of the quadrangle
- chotcrd.txt - map credits
- chotdisc.txt – USGS disclaimer statement
- chotref.txt - text file listing map references

Appendix B - ArcInfo Macro Language program (chot250k.aml) used to plot the geologic map of the Choteau quadrangle

```
/*  chot250k.aml, 6/15/2001, pd

/*  This Arc/Info Macro Language (AML)
program will plot the geologic map sheet in color
for the Choteau quadrangle at 1:250,000 scale.
/*  To run this AML:
/*     1. Type '&run chot250k' at the 'Arc:' prompt,
/*     2. Run the Arc/Info HPGL2 command to
convert the GRA file to an HPGL2 file, i.e., hpgl2
chot250k chot250k.hp # 1.0 opaque # 0 # # #
cal.dat
/*     3. Execute the UNIX 'lpr' command to print
the 1:250,000-scale geologic map on your plotter,
i.e., lpr -Ppicasso chot250k.hp
/* ************************

arcplot
display 1040
chot250k.gra

clear
clearselect

pagesize 43.0 28.0
pageunits inches
mapunits meters
mapscale 250000
mapposition ll 0.75 6.0
mapangle 0.2

/*set variables
&set cover chot250k
&set pointcov chot250p
&set quad c250box
&s credits chotcrd.txt
&s disclaimer chotdisc.txt
&s logo usgslogo.gra
&s reference chotref.txt
&set key1 chotpoly.key
&set key2 chotlin2.key

/*set map parameters
&label mapparameters
mape %cover%
maplimits 0.0 2.4 26 26

/*draw outside box
linesymbol 9
linecolor 1
box 0.5 0.5 35.5 27.5
textquality proportional
textfont 94021
linedelete all

/* cut marks
markerset plotter
markersymbol 1
markersize 0.1
marker 0 0
marker 0 28
marker 36.0 0
marker 36.0 28

&label shadepolys
/* color polygons for geologic rock units
shadedelete all
shadeset wpgcmyk.shd
polygonshade %cover% unit %cover%.ru

&label contacts
/* plot contacts
linedelete all
lineset geol_sfo.lin
asel %cover% arcs
res %cover% arcs linecode gt 0 and linecode lt 42
arclines %cover% linecode %cover%.con
asel %cover% arcs

&label structures
/* plot structures with line patterns
linedelete all
lineset geol_sfo.lin
asel %cover% arcs
res %cover% arcs linecode gt 100 and linecode lt
800
arclines %cover% linecode %cover%.st2
asel %cover% arcs
res %cover% arcs linecode gt 800 and linecode lt
810
arclines %cover% linecode %cover%.lgu
asel %cover% arcs

&label struct-symbol
markerdelete all
```

```
markerset geoscamp2.mrk
pointmarkers %pointcov% symbol

&label mapquad
/* plot quadrangle boundary
linedelete all
lineset plotter
linesymbol 5
arcs %quad%

&label geolabels
textsize 0.10
res %cover% poly area gt 400000
labeltext %cover% unit %cover%.ru cc
asel %cover% poly

&label titles
plot %logo% box 2 25.75 5 26.75
textfont 93715
textquality kern
textsize 0.35
move 6 26.35
text 'U.S. Department of the Interior'
move 6 25.9
text 'U.S. Geological Survey'
move 34.5 26.5
text 'Miscellaneous Investigations Map Series I-1300' lr
move 34.5 26.0
text 'Database, version 1.0' lr
move 34.5 25.5
text 'Sheet 1' lr
move 15.6 26.25
text 'Prepared in cooperation with'
move 16.1 25.85
text 'the U.S. Forest Service'
textfont 93711
textsize 0.3
move 13.325 6.75
text 'Geology'
textsize 0.4
move 13.85 6.05
text 'Geologic and Structure Map of the Choteau 1ø x 2ø Quadrangle, Western Montana: A Digital Database' lc
textsize 0.3
move 13.68 5.65
text 'By'
textsize 0.3
move 13.95 5.1
text 'M. R. Mudge, R. L. Earhart, J. W. Whipple and J. E. Harrison' lc
textsize 0.3
move 12.57 4.5
text 'Digital database by'
move 14.1 4
text 'Steven R. Munts and Jeffery T. Silkwood' lc
move 13.925 3.5
text '2001' lc
textsize 0.2
move 13.93 3.0
text '(map originally published in 1982)' lc

&label explan
/* plot explanation - geologic units
shadedelete all
shadeset wpgcmyk.shd
textfont 93711
textsize 0.20
move 26.75 25.0
text 'Explanation'
textsize 0.12
textquality proportional
textfont 94021
keyarea 26.75 10.1 44.5 24.5
keybox 0.5 0.25
keyseparation 0.2 0.2
keyshade %key1%

&label linekey
/*  plot explanation - line key
linedelete all
lineset geol_sfo.lin
keybox 0.6 0.0
keyline %key2% nobox
linedelete all

&label index-map
plot indexmap.gra box 29 6.75 33.9 8.75
textfont 93713
textquality proportional
textsize 0.12
move 29 6.625
text 'Index map showing Choteau quadrangle'

&label references
/* list references
textfont 93711
textsize 0.25
textcolor 1
move 29 5.8
text 'References'
move 29 5.5
textsize 0.12
textquality proportional
textfont 94021
textfile %reference%
```

```
&label disclaimer
textfont 93713
textquality proportional
textsize 0.12
move 29 3.7
textfile %disclaimer%

&label credits
/*list credits
textfont 93713
textquality proportional
textsize 0.12
move 23 7.1
textfile %credits%

&label proj
/*plot map projection notes
textfont 93713
textquality proportional
textsize 0.12
move 2.0 7.0
text 'map projection: Transverse; units: Meters'
move 2.0 6.8
text 'spheroid: Clarke1866; datum: NAD27'

&label scale
/* plot scale bars
linedelete all
lineset plotter
textfont 94021
textsize 0.12
&r scale2a 13.93 2.55 other 250000

&label lat-long
/* plot neat line labels (latitude and longitude)
mape %quad%
linecolor 1
mapprojection geo.prj trans.prj
neatline -114 47.0 -112 48.0 geo.prj
neatlinehatch 0.25000 0.25000 0.2 0 geo.prj
textset font.txt
textsymbol 1
textsize 8 pt
textstyle typeset
textoffset -0.35 0.15
neatlinelabels 0.25000 top all geo.prj dms
'%1%!pat1857; %2%!pat1727; %3%!pat1728'
textoffset -0.75 0.0
neatlinelabels 0.25000 left all geo.prj dms
'%1%!pat1857; %2%!pat1727; %3%!pat1728'


&label done
quit

display 9999 3
draw chot250k.gra
&return
```

Appendix C - Metadata file (chot250k.met) for the Choteau GIS

Identification_Information:
Citation:
Citation_Information:
Originator:
Melvill R. Mudge, Robert L. Earhart, James W. Whipple, Jack E. Harrison, Steven R. Munts, and Jeffery T. Silkwood
Publication_Date: 2000
Title:
Geologic and structure map of the Choteau 1 x 2 degree quadrangle, western Montana: a digital database.
Western Montana: a digital database.
Edition: Version 1.0
Geospatial_Data_Presentation_Form: map
Series_Information:
Series_Name: Miscellanious Investigations Series
Issue_Identification: Map I-1300
Publication_Information:
Publication_Place: Menlo Park, CA
Publisher: U. S. Geological Survey
Online_Linkage: URL = http://geopubs.wr.usgs.gov/i-map/i1300/

Description:

Abstract:

The geologic and structure map of Choteau 1 x 2 degree quadrangle (Mudge and others, 1982) was originally converted to a digital format by Jeff Silkwood (U.S. Forest Service and completed by the U.S. Geological Survey staff and contractor at the Spokane Field Office (WA) in 2000 for input into a geographic information system (GIS). The resulting digital geologic map (GIS) database can be queried in many ways to produce a variey of geologic maps. Digital base map data files (topography, roads, towns, rivers and lakes, etc.) are not included: they may be obtained from a variety of commercial and government sources. This database is not meant to be used or displayed at any scale larger than 1:250,000 (e.g. 1:100,000 or 1:24,000. The digital geologic map graphics and plot files (chot250k.gra/.hp/.eps and chot-map.pdf) that are provided in the digital package are representations of the digital database. They are not designed to be cartographic products.

Purpose:

This dataset was developed to provide geologic map GIS of the Choteau 1:250,000 quadrangle for use in future spatial analysis by a variety of users. These data can be printed in a variety of ways to display various geologic features or used for digital analysis and modeling. This database is not meant to be used or displayed at any scale larger than 1:250,000 (e.g. 1:100,000 or

1:24,000).

Supplemental_Information:
This GIS consists of two major Arc/Info datasets, a line and polygon file (chot250k) containing geologic contact and structures (lines) and geologic map rock units (polygons), and a point file (chot250kp) containing structural point data for plunging folds.

Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 2000
Currentness_Reference: Publication date

Status:
Progress: complete
Maintenance_and_Update_Frequency: As needed.

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -114.00
East_Bounding_Coordinate: -112.00
North_Bounding_Coordinate: 48.00
South_Bounding_Coordinate: 47.50

Keywords:
Theme:
Theme_Keyword_Thesaurus: none
Theme_Keyword: geology
Place_Keyword_Thesaurus: none
Place_Keyword: Montana
Place_Keyword: Choteau
Place_Keyword: Powell County
Place_Keyword: Lewis and Clark County
Place_Keyword: Lake County
Place_Keyword: Flathead County
Place_Keyword: Missoula County
Place_Keyword: Teton County
Place_Keyword: Pacific Northwest
Place_Keyword: USA

Access_Constraints: none

Use_Constraints:
This digital database is not meant to be used or displayed at any scale larger than 1:250,000 (e.g. 1:100,000).

Any hardcopies utilizing these data sets shall clearly indicate their source. If the user has modified the data in any way they are obligated to describe the types of modifications they have performed on the hardcopy map. User specifically agrees not to misrepresent these data sets, nor to imply that changes they made were approved by the US Geological Survey.

Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Pamela D. Derkey
Contact_Organization: U.S. Geological Survey
Contact_Position: geologist
Contact_Address:
Address_Type: mailing and physical address
Address: 904 W. Riverside Ave., Rm. 202
City: Spokane
State_or_Province: WA
Postal_Code: 99201
Country: USA
Contact_Voice_Telephone: 1-509-368-3114
Contact_Facsimile_Telephone: 1-509-368-3199
Contact_Electronic_Mail_Address: pderkey@usgs.gov

Data_Set_Credit:
The Choteau geologic map database was initially prepared by Jef Silkwood (U.S. Forest Service) from the geologic map by Mudge and others (1982). These preliminary digital files were transferred to the U.S. Geological Survey (USGS) in 1999. Robert J. Miller (USGS) merged the geology (lines and polygons) and structure (lines) files into a single topological ArcInfo dataset. Steven R. Munts (contractor) digitized additional structural features (folds) from Mudge and others (1982). The digital files were then augmented with an interim geologic map data model (data base), further attributed and edited, and then plotted and compared to the published geologic map to check for digitizing and attribute errors. All processing by the U.S. Geological Survey was done in ArcInfo version 7.2.1 installed on a Unix-based Sun Ultra workstation.

Pamela D. Derkey and Robert J. Miller (both of the USGS) provided technical assistance with the geologic systems data model, metadata, digital documentation, and map projections; Steven R. Munts (contractor) digitized new linework, edited digital files, combined existing data sets, built look-up tables, and prepared the composite dataset.
Native_Data_Set_Environment: SunOS, 5.7, sun4u UNIX ARC/INFO version 7.2.1

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Attribute accuracy was verified by manual comparision of the source with hard copy printouts, plots, and on-screen evaluation.

Logical_Consistency_Report:
Polygon and chain-node topology present. Segments making up the outer and inner boundaries of a polygon tie end-to-end to completely enclose the area. Line segments are a set of sequentially numbered coordinate pairs. No duplicate features

exist nor duplicate points in a data string. Intersecting lines are separated into individual line segments at the point of intersection. All nodes are represented by a single coordinate pair, which indicates the beginning or end of a line segment. The neat line was generated by mathematically generating the four sides of the quadrangle, densifying the lines of latitude and projecting the file to a Transverse projection (without a y-shift).

Completeness_Report:
All geologic units were compiled from Mudge and others (1982) at a scale of 1:250,000.

Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
The horizontal position accuracy for the digital data is no better than 55 meters based on the digitizing RMS error.

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Mudge, M.R., Earhart, R.L., Whipple, J.W., and Harrison, J.E.
Publication_Date: 1982
Title:
Geologic and structure map of the Choteau 1 x 2 degree quadrangle, western Montana
Geospatial_Data_Presentation_Form: map
Series_Information:
Series_Name: Miscellaneous Investigations Series
Issue_Identification: Map I-1300
Publication_Information:
Publication_Place: Denver, CO
Publisher: U.S. Geological Survey
Source_Scale_Denominator: 250000
Type_of_Source_Media: paper map
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 1982
Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: Mudge and others (1982)
Source_Contribution: This is the source for all the datasets.

Process_Step:
Process_Description:
Geologic map (Mudge and others, 1982) was initially prepared by Jef Silkwood (U.S. Forest Service) and given minimal attributing. Lithology and faults were digitized (1999)

The contacts, lithology and faults datasets were

compiled electronically into a single topologically correct coverage by R. J. Miller (USGS) using ARC/INFO ver. 7.2.1 on a Sun Unix system (December, 1999).

S. R. Munts (contractor) edited the dataset and attributed it with an interim geologic data model. He also digitized the folds from Mudge and others (1982) on an Altek digitizing tablet (RMS input error = 0.003) and incorporated the data into the Choteau GIS.
Process_Date: 1999 - 2001

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Point
Point_and_Vector_Object_Count: 3007
SDTS_Point_and_Vector_Object_Type: String
Point_and_Vector_Object_Count: 8382
SDTS_Point_and_Vector_Object_Type: GT-polygon composed of chains
Point_and_Vector_Object_Count: 3006

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Transverse Mercator
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 1.00000000
Longitude_of_Central_Meridian: -113
Latitude_of_Projection_Origin: 0
False_Easting: 0.000
False_Northing: 0.00000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000000266566
Ordinate_Resolution: 0.000000266566
Planar_Distance_Units: Meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1927
Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.4
Denominator_of_Flattening_Ratio: 294.98

Entity_and_Attribute_Information:
Overview_Description:
Entity_and_Attribute_Overview:
The 'Geologic and structure map of the Choteau 1 x 2 degree quadrangle, Montana: a digital database' report (chot250k.pdf) contains a detailed description of each attribute code and a reference to the associated map symbols on the map source materials. The GIS includes a geologic line work arc attribute

table, chot250k.aat, that relates to the chot250k.con (contact look-up table), chot250k.st2 (structure look-up table), chot250k.lgu (linear geologic units table), and the chot250k.ref (source reference look-up table) files; and a rock unit polygon attribute table, chot250k.pat, that relates to the chot250k.ru (rock unit look-up table) and chot250k.ref (source reference look-up table) files; and a point attribute table, chot250kp.pat, that relates to the chot250p.sym (symbol description look-up table) and the chot250p.ref (source reference look-up table).

Entity_and_Attribute_Detail_Citation:
See Chot250k.pdf file available at http://geopubs.wr.usgs.gov/i-map/i1300/ for a detailed description of the items in the database.

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization:
U.S. Geological Survey Information Services
Contact_Address:
Address_Type:
Address:
City:
State_or_Province:
Postal_Code:
Country:
Contact_Voice_Telephone:

Distribution_Liability:
The U.S. Geological Survey (USGS) provides these geographic data "as is". The USGS makes no guarantee or warranty concerning the accuracy of information contained in the geographic data. The USGS further makes no warranties, either expressed or implied as to any other matter whatsoever, including, without limitation, the condition of the product, or its fitness for any particular purpose. The burden for determining fitness for use lies entirely with the user. Although these data have been processed successfully on computers at the USGS, no warranty, expressed or implied, is made by the USGS regarding the use of these data on any other system, nor does the fact of distribution constitute or imply any such warranty.

In no event shall the USGS have any liability whatsoever for payment of any consequential, incidental, indirect, special, or tort damages of any kind, including, but not limited to, any loss of profits arising out of use of or reliance on the geographic data or arising out of the delivery, installation, operation, or support by USGS.

This digital geologic map GIS of the Choteau 1:250,000 quadrangle, Montana, is not meant to be used or displayed at any scale larger than 1:250,000 (e.g. 1:100,000 or 1:24,000).

Metadata_Reference_Information:

Metadata_Date: 20010615
Metadata_Contact:
  Contact_Information:
    Contact_Organization_Primary:
      Contact_Organization: U.S. Geological Survey
      Contact_Person: Pamela D. Derkey
    Contact_Position: geologist
    Contact_Address:
      Address_Type: mailing and physical address
      Address: 904 West Riverside Avenue, Rm 202
      City: Spokane
      State_or_Province: WA
      Postal_Code: 99201
      Country: USA
    Contact_Voice_Telephone: 1-509-368-3114
    Contact_Facsimile_Telephone: 1-509-368-3199
    Contact_Electronic_Mail_Address: pderkey@usgs.gov
Metadata_Standard_Name: Metadata
Metadata_Standard_Version: EGDC-STD-001-1998
Metadata_Access_Constraints: none
Metadata_Use_Constraints: none