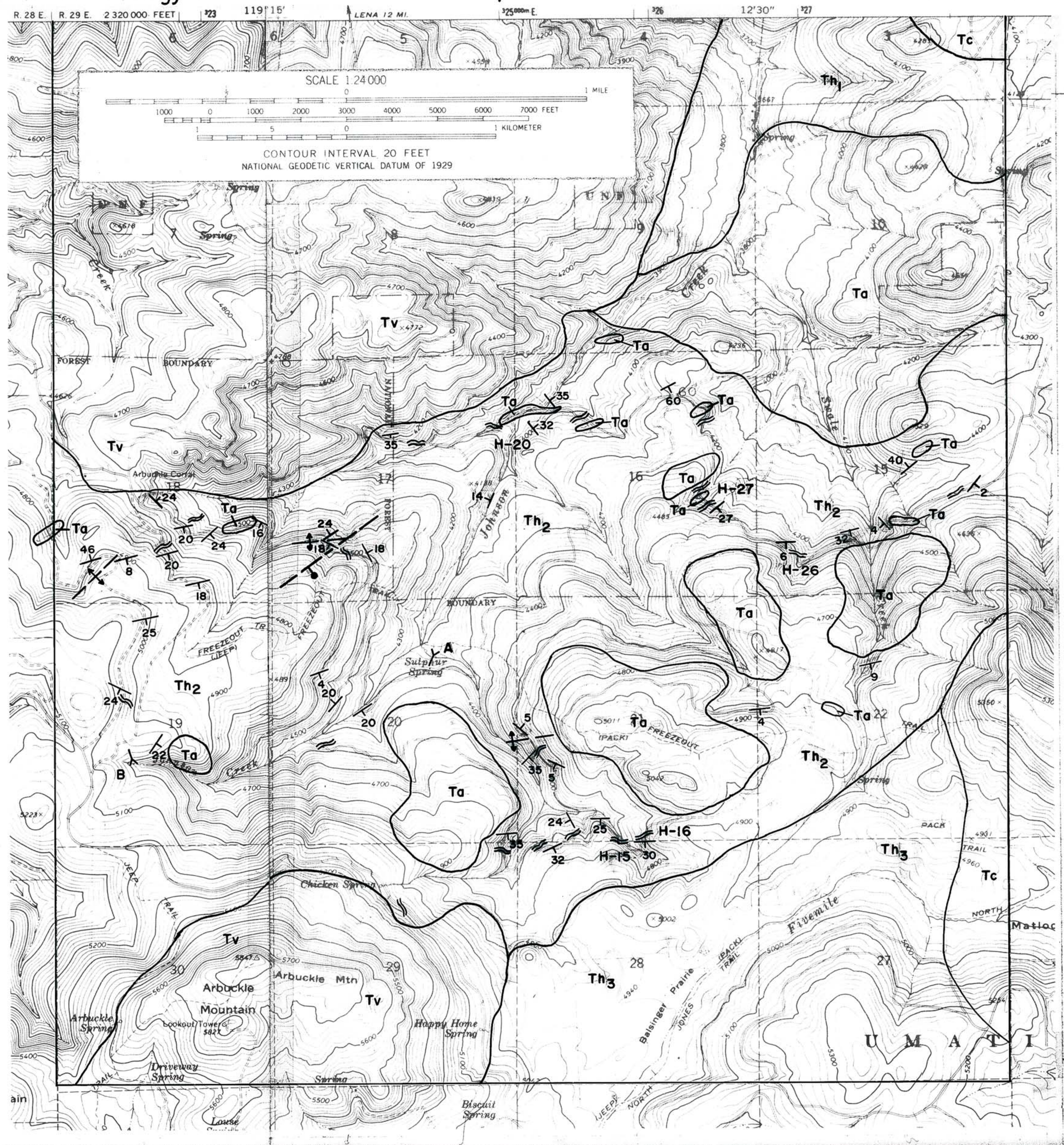
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

Part A - Geology of the Johnson Creek area, Matlock Prairie and Arbuckle Mtn. quadrangles (1:24,000 scale)



EXPLANATION - PART A

Tc Columbia River Basalt Group (mostly basalt flows)

Tv Eocene to Oligocene andesite flows, breccias, and tuffs; equivalent to the Clarno Formation

Ta Eocene andesite porphyry dikes, sills, and flows(?)

Paleocene to Eocene arkosic sandstones of the Herren formation (unit **Th** of Part B) subdivided into three members:

- Th_3 Feldspathic arenite sandstones
- Th_2 Micaceous sandstones and carbonaceous siltstones with interbedded lignite coal seams
- Th_1 Arkosic sandstones

Coal Prospects

A. Johnson Creek
B. Clarke

H-15 Locality referred to in text

Coal or lignite seam

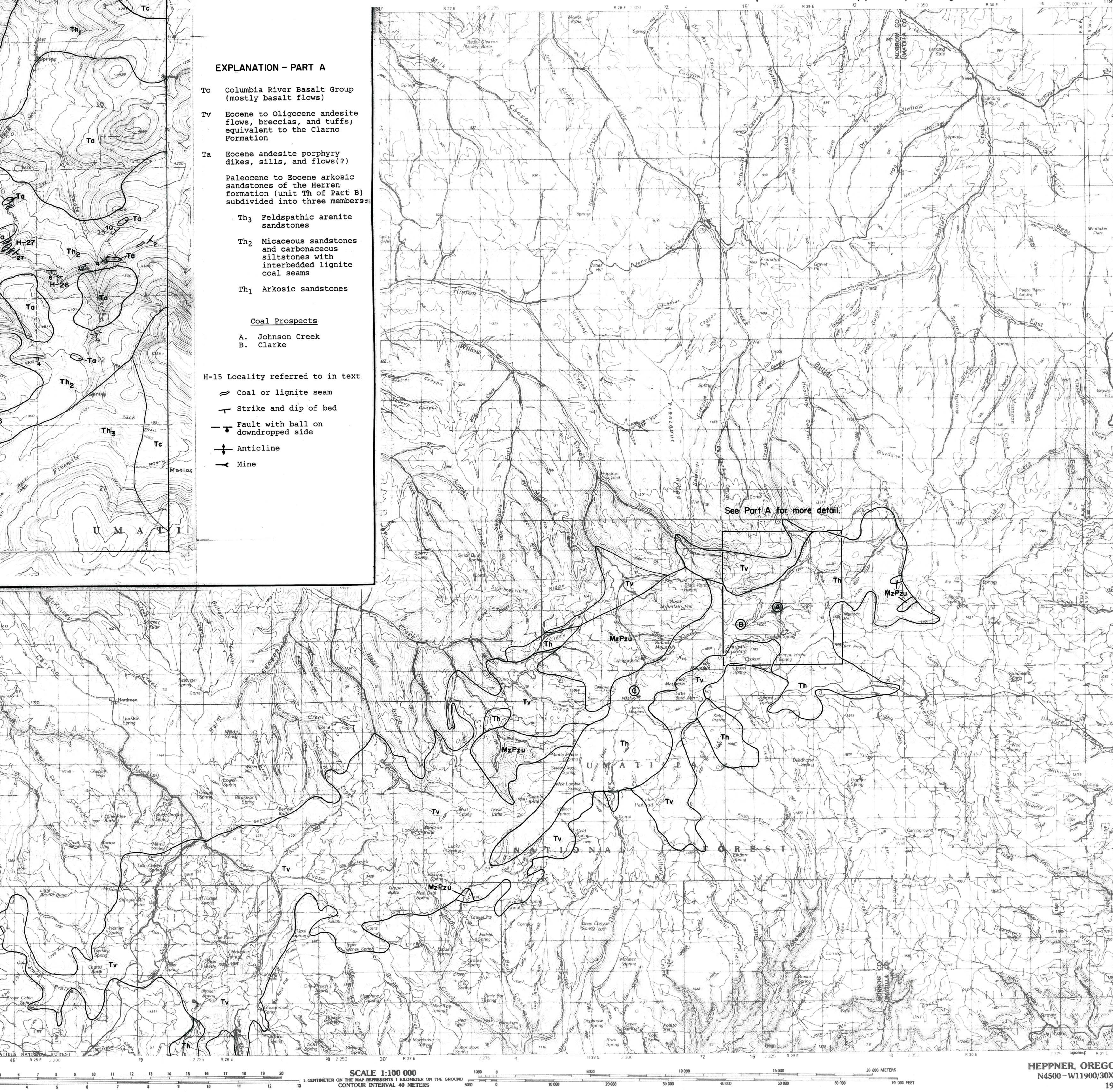
Strike and dip of bed

Fault with ball on downdropped side

Anticline

Mine

Part B - Distribution of pre-Columbia River Basalt Group rocks and coal prospects in the southern part of the Heppner quadrangle (1:100,000 scale)



Open-File Report O-86-5

GEOLOGY AND COAL RESOURCES OF THE ARBUCKLE MOUNTAIN COAL FIELD, MORROW COUNTY, OREGON

By Mark L. Ferns and Howard C. Brooks

Funded in part by
U.S. Bureau of Land Management
Contract number OR920-4121-06-2518
And the U.S. Forest Service

EXPLANATION - PART B

Tv Eocene to lower Miocene(?) andesite and silicic volcanic rocks; includes flows, breccias, and tuffs of the Clarno and John Day Formations

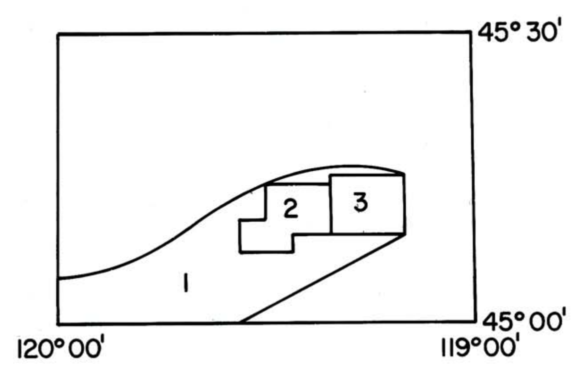
Th Paleocene to Eocene arkosic sedimentary rocks of the Herren formation; includes porphyritic andesites (unit **Ta** of Part A)

MzPzu Undifferentiated metamorphic and igneous intrusive rocks of Mesozoic and/or Paleozoic age

Coal Prospects

A. Johnson Creek
B. Clarke
C. Willow Creek

Compiled from previous geologic maps by (1) Walker (1973) and (2) Shorey (1976) and from (3) reconnaissance geologic mapping by Ferns and Brooks in 1985



STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

910 State Office Building
1400 Southwest Fifth Avenue
Portland, Oregon 97201

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NOTICE

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, this paper has not been edited to our usual standards.

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PLATE (folded)

INTRODUCTION

This report describes the geology of lignite coal resources in the Arbuckle Mountain coal field in southeastern Morrow County, Oregon (Figure 1). The geologic map of parts of the Arbuckle Mountain and Matlock Prairie 7½-minute quadrangles shown in Plate 1, Part A, resulted from 10 days of field work conducted by the authors in the fall of 1985. Plate 1, Part B, which shows known coal prospects and the distribution of pre-Columbia River Basalt Group strata at a scale of 1:100,000, was compiled from that work and earlier maps by Walker (1973) and Shorey (1976). Much of the information presented here on the regional geology and the history of the coal deposits is based on previous reports listed in the bibliography, especially those by Mendenhall (1907), Allen (1947), Pigg (1961), and Shorey (1976).

Coal was discovered in the Heppner area in about 1878. Subsequent exploration and road construction have revealed a number of discontinuous seams and lenses of low-grade coal a few inches to a few feet thick that are interbedded with carbonaceous shales and arkosic sandstones of Paleocene to Eocene age. Total production from the Arbuckle Mountain coal field probably does not exceed 100 tons of coal. Future production of significant amounts of coal from the known deposits in the area seems unlikely.

The Arbuckle Mountain coal field is centered about 20 mi (30 km) southeast of Heppner via Willow Creek and 18 mi (29 km) west of Ukiah via paved Forest Service Road 53. The known coal deposits occur near the heads of Willow Creek and Johnson Creek on the north flank of Arbuckle Mountain in T. 4 S., Rs. 28 and 29 E. The area is generally densely forested, particularly on the north-facing slopes. Except for road cuts, the bed rock is poorly exposed throughout the coal-bearing area. Precipitation averages about 17 in. (43 cm) per year, and snowfall averages about 40 in. (102 cm)

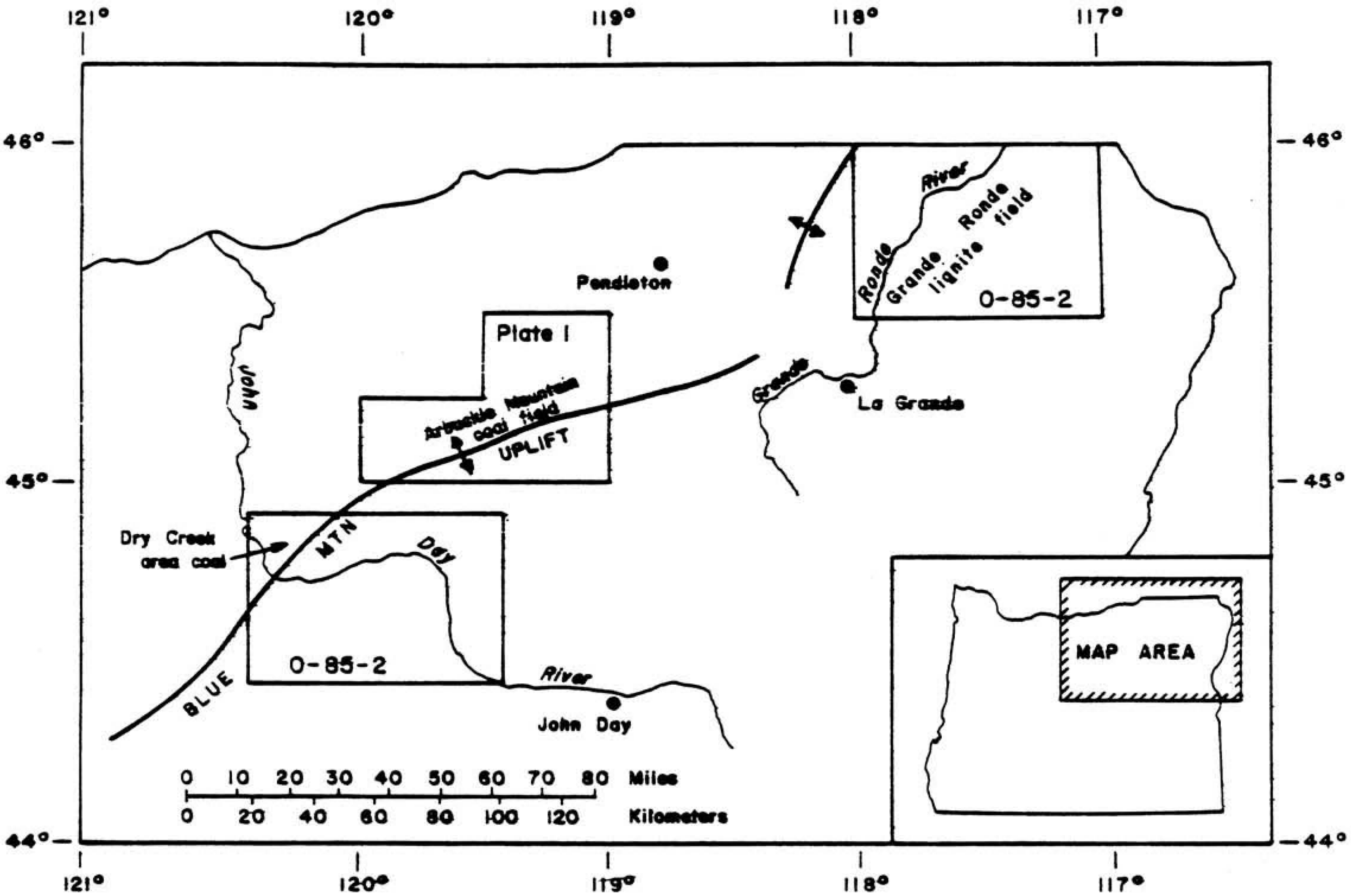

Figure 1. Map showing location of Arbuckle Mountain coal field, Grande Ronde lignite field, area covered by Plate 1 of this study, and areas covered by Open-File Report 0-85-2 (Ferns, 1985).

per year at Ukiah. Most of the coal occurrences are in the Umatilla National Forest. Some of the deposits southeast of Johnson Creek are on private land. The USDA Forest Service boundary in that area has been altered by land exchanges from that shown on the Matlock Prairie sheet. The major private land holders in the area include the Kinzua Logging Company and the Hughes Ranch. There is a fairly dense network of unpaved logging roads in the Johnson Creek area, some of which are barred by locked gates erected for a variety of reasons.

This report has benefited from review by Michael L. Cummings, Portland State University, and Daniel G. Avery, USDA Forest Service, for which the writers are grateful. The report is partially funded by the USDI Bureau of Land Management under Contract Number OR920-4121-06-2518 and by the USDA Forest Service.

REGIONAL GEOLOGY

The Arbuckle Mountain coal field is located along the crest of the Blue Mountain anticline, a broad, northeast-trending regional warp across which the Miocene basalt flows of the Columbia River Basalt Group thin (Walker, 1973). The Grande Ronde lignite field and coal prospects in the Dry Creek area, which also lie along the crest and flanks of the Blue Mountain anticline (Figures 1 and 2), have been previously described by Ferns (1985).

Rocks older than those of the Columbia River Basalt Group that are exposed along the crest of the Blue Mountains in the Heppner area (Plate 1, Part B) include a basement complex of metamorphic and intrusive rocks of Paleozoic and Mesozoic age, an arkosic continental Paleocene- to Eocene-age sedimentary sequence containing the coal deposits, and volcanic and volcaniclastic rocks of Eocene to early Miocene(?) age.

Basement complex

The basement complex is comprised of metagabbro, phyllite, metachert, quartz-mica schist and gneiss, amphibolite, and minor serpentinite of Paleozoic and Mesozoic age, and quartz diorite intrusives of presumed Late Jurassic age (Walker, 1973; Shorey, 1976). According to Shorey (1976), the quartz-mica schists contain muscovite, biotite, and occasional garnet, while metamorphism in the gabbros is manifested by partial replacement of pyroxenes by fibrous amphiboles (tremolite/actinolite). The quartz diorite intrusions are relatively unmetamorphosed and are composed mainly of quartz, plagioclase, biotite, and hornblende (Shorey, 1976).

Paleocene and Eocene sedimentary rocks

The basement complex is overlain in angular unconformity by a sequence of arkosic sandstones and shales,

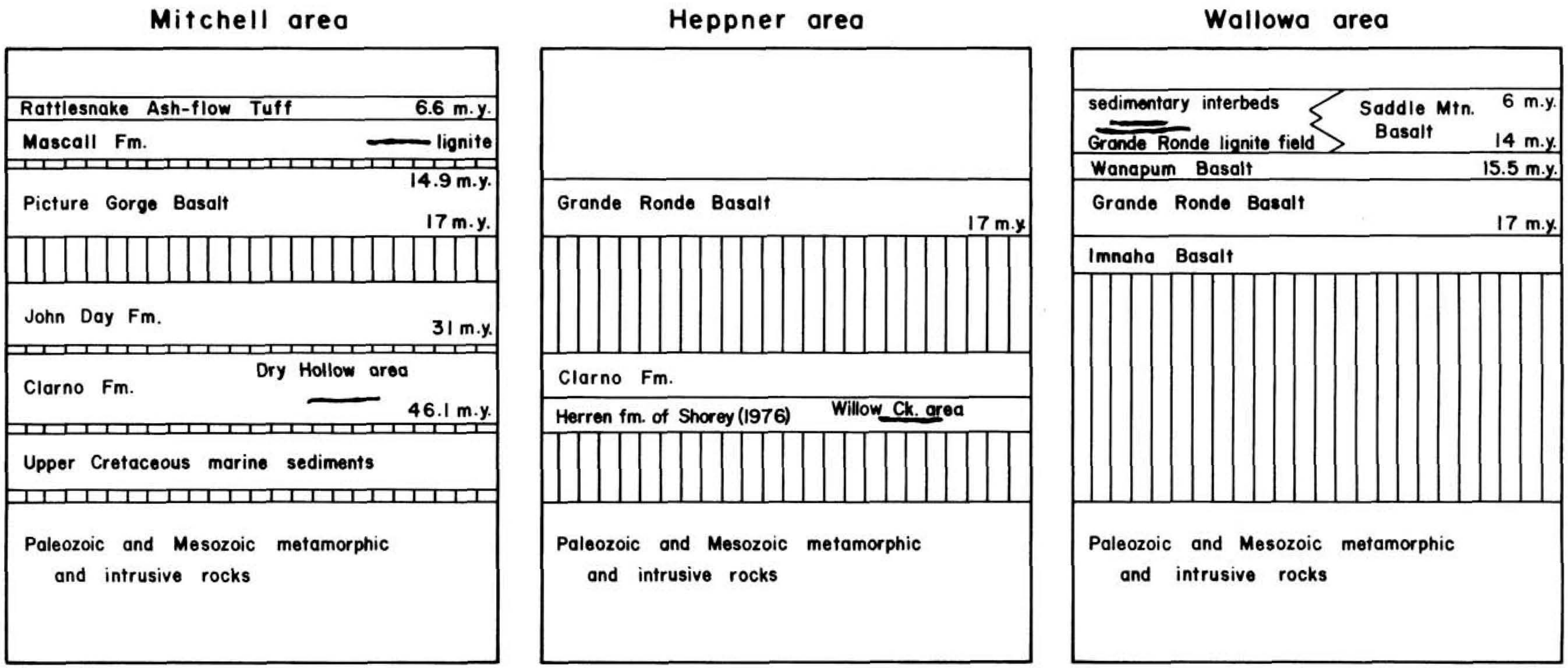

Figure 2. Stratigraphic correlation chart. Horizontal lines indicate lignite and/or coal. Figure modified from Ferns (1985). Data after Barrash and others (1980) and Stoffel (1984).

informally named the Herren formation by Shorey (1976) for exposures in the Herren Meadows area along the headwaters of Willow Creek. The Herren formation is comprised mainly of white, orange-yellow, or buff-colored, medium- to coarse-grained arkosic sandstones with subordinate shale and siltstone layers and carbonaceous shales and lignite coal beds. The sandstones, which range from well indurated to friable, are thick bedded and generally massive in outcrop. Cross-bedded sandstones are found in some areas. Neither the top nor the bottom of the Herren formation is well defined. The total thickness of the formation has been estimated at slightly less than 2,000 ft (610 m) (Mendenhall, 1907; Pigg, 1961; Shorey, 1976).

Porphyritic andesite is intrusive into and/or interlayered with the sedimentary rocks in the headwaters of Johnson Creek (Plate 1, Part A). Pigg (1961) estimated that 35 percent of the unit in the East Birch Creek area, which is located about 28 mi (45 km) northeast of Arbuckle Mountain, is comprised of interbedded tuff and dacite and rhyolite porphyry intrusions and/or flows.

Floral dates on the Herren formation range from Paleocene to late Eocene. Fritts and Fisk (1985) consider the Herren formation to be predominantly Paleocene in age, based on plant fossils. Gordon (1985) identified the Paleocene water fern Hydromystria from the Denning Spring locality in the East Birch Creek area. Pigg (1961), Hogenson (1964), Trauba (1975), and Shorey (1976) all reported leaf fossils indicative of an early to late Eocene age.

Eocene and Oligocene volcanic and volcaniclastic rocks

The Herren formation is overlain by porphyritic andesite flows, mudflow breccias, and tuffs that have been correlated with the late Eocene-early Oligocene Clarno Formation (Pigg, 1961; Shorey, 1976). The Clarno Formation is typically made up of coalescing lava flows, mudflows, and tuffaceous deposits that have little lateral continuity and therefore are assumed to be from local sources, although few vent areas have been identified.

Walker (1973) shows the arkosic sedimentary rocks in the southwest corner of the Heppner 1:100,000 sheet (Plate 1, Part B) to be directly overlain by tuffaceous sediments and ash-flow tuffs that are believed to be correlative with the John Day Formation. The tuffs are reported to contain interbedded conglomerates rich in basement-complex clasts (Walker, 1973).

The age of the overlying volcanic rocks in the Arbuckle Mountain area is not well known. Previous correlations with the Clarno Formation in this area were based in part on Eocene plant fossils (Pigg, 1961; Hogenson, 1964) that were found in the underlying Herren formation.

STRATIGRAPHY

Pigg (1961) was the first to recognize that the arkosic continental sedimentary rocks comprising the Herren formation in the Arbuckle Mountain coal field were older and separate from the overlying andesite flows and breccias. Earlier workers (Mendenhall, 1907; Collier, 1914) considered the sediments to be part of the Clarno Formation. Shorey (1976) remapped part of the area described by Pigg and informally named the unit the "Herren formation."

The authors' work in the Johnson Creek drainage east of the area mapped by Pigg (1961) and Shorey (1976) indicates that the Herren formation in that area consists of three members. Due to the limited time available for mapping the this study, the boundaries between members shown on Plate 1, Part A, are only approximate.

The basal member (member $\mathbf{Th_1}$) consists of white, medium- to coarse-grained arkosic sandstones that were previously mapped by Walker (1973) as part of his fluvial sandstone unit (unit **Tsf**). Member $\mathbf{Th_1}$ is best exposed in the Butter Creek drainage east of Johnson Creek, where it is marked by a coarse conglomerate that contains locally derived quartz diorite clasts up to 10 in. (25.4 cm) in diameter. Member $\mathbf{Th_1}$ is estimated to be about 300 ft (91 m) thick in this area and consists of white and buff-colored, coarse-grained arkosic sandstones that overlie deeply weathered Late Jurassic quartz diorite basement.

Basal arkosic sandstones in the Willow Creek drainage (Shorey, 1976) and on the north side of Johnson Creek are interbedded with rare conglomerate lenses containing well-rounded chert clasts that are up to 3 in. (7.6 cm) in diameter. In thin section, member $\mathbf{Th_1}$ sandstones are matrix-poor arkoses that are comprised of about 65 percent quartz and 30 percent feldspar grains. Lithic fragments include chert, siliceous metamorphic rocks, and quartz diorite presumably derived from the underlying basement complex. Muscovite is a common accessory mineral, but biotite is rare. Other accessory minerals include apatite, zircon, and sphene. Although some samples are cemented by calcite, silica cement is most common.

A sequence of poorly exposed micaceous sandstones and siltstones comprises member $\mathbf{Th}_2$, which is estimated to be about 150 ft (46 m) thick where it overlies the basal sandstones in the Butter Creek area. Member $\mathbf{Th}_2$ thickens to the west in the Johnson Creek area (Plate 1, Part A), where it is exposed over an area of about 11 mi^2 (28 km^2). Member $\mathbf{Th}_2$ contains the lignite coal seams that constitute the Arbuckle Mountain coal field and was previously mapped as a sandstone, siltstone, and shale unit (unit Tss) by Walker (1973). The micaceous sedimentary rocks are poorly exposed and have been folded about northeast-trending fold axes that parallel the trend of the Blue Mountain anticline. Member $\mathbf{Th}_2$ is comprised mainly of fine- to coarse-grained, white to greenish-gray micaceous sandstone beds that range from 1 to 20 ft (0.3 to 6 m) in thickness. Interbedded siltstones and shales are usually greenish-gray in color and range from 1 to 10 ft (0.3 to 3 m) in thickness. The siltstones are locally rich in organic matter and locally grade into seams of nearly pure lignite coal.

In thin section, the micaceous sandstones are matrix-poor, biotite arkoses cemented by either silica or calcite. The arkoses contain from 50 to 69 percent quartz and 24 to 38 percent feldspar grains. The latter include about equal amounts of plagioclase and potassium feldspar. The plagioclase grains are usually partially altered to white mica and/or calcite. Muscovite and biotite are commonly deformed by post-depositional compaction. Chert and siliceous metamorphic clasts constitute less than 10 percent of the grains. Accessory minerals include garnet, epidote, and zircon.

Plagiophyric andesites (unit **Ta**) intrude or are interbedded with micaceous member $\mathbf{Th}_2$ in the Johnson Creek area (Plate 1, Part A). Tabular masses range from 3 to 60 ft (1 to 18 m) in thickness. Contact relationships with the surrounding sedimentary rocks are poorly defined. The bases of the andesites are usually marked by spheroidal weathering zones that grade upward into massive andesite. The tops of the andesites are generally conformable with the overlying sediments but do not exhibit vesicular zones or breccias. The bases of the andesites are not marked by either breccias or conglomerates that might indicate flow affinities.

The andesite masses that crop out near the southern margin of member $\mathbf{Th}_2$ (Plate 1, Part A) mark a discontinuous zone near the stratigraphic top of the member and may represent andesite flows. Alternatively they may mark a series of sills that were intruded along relatively incompetent horizons in member $\mathbf{Th}_2$. It is noteworthy that no similar tabular-shaped andesite porphyry masses have been found in either the overlying or underlying sandstone members. Shorey (1976) found no interbedded volcanic rocks in the Willow Creek area to the west but did note a 3-ft (1-m) -thick porphyritic andesite sill exposed along the Smith Ditch in the SE¼ SW¼ sec. 34, T. 4 S., R. 28 E., and a siliceous porphyritic volcanic rock that is apparently stratigraphically below the arkosic sedimentary rocks in the NW¼ sec. 30, T. 4 S., R. 28 E.

There are two possible explanations for the patchy distribution of the porphyritic andesites (Plate 1, Part A). The exposures may be erosional remnants of lithologically similar flows that once covered the area in which the outcrops occur. Alternatively, the exposures may represent areally restricted flows or sills emplaced near local vent areas. The second alternative seems the most likely, given the lack of eroded volcanic material in the overlying sandstones.

Similar-appearing porphyritic andesite flows and breccias mark the base of the overlying Eocene-Oligocene volcanic sequence (unit **Tv**) north of Johnson Creek. These flows were apparently erupted from a local vent that may be related to an area of hydrothermal alteration in secs. 11 and 14, T. 4 S., R. 29 E., where quartz veins cut the exposed andesite porphyry mass and where the adjacent arkosic sandstones are silicified and locally cut by small quartz stringers.

The southern part of the Johnson Creek area is overlain by a sequence of highly weathered, friable, orange-yellow, medium- to coarse-grained feldspathic arenites that comprise member $\mathbf{Th}_3$. The sandstones are commonly cross bedded and were previously mapped as part of the fluvial sandstone unit (unit Tsf) of Walker (1973). Thin, white tuff lenses are found within member $\mathbf{Th}_3$, which locally contains carbonized wood fragments. The contact between member $\mathbf{Th}_3$ and the micaceous sandstones and siltstones of member $\mathbf{Th}_2$ to the north is not exposed, but consistent dips to the south in member $\mathbf{Th}_3$ suggest that the feldspathic arenites of member $\mathbf{Th}_3$ overlie the micaceous sandstones and siltstones of member $\mathbf{Th}_2$.

In thin section, member $\mathbf{Th}_3$ sandstones are matrix-poor, silica-cemented feldspathic arenites comprising about 88 percent quartz and 10 percent potassium feldspar grains. Iron oxide coating of the grains gives the sandstones their characteristic orange and yellow color. Accessory minerals include zircon, apatite, and tourmaline. The arenites contain abundant muscovite but no biotite. Most of the quartz grains are strained and exhibit undulatory extinction.

COAL PROSPECTS

Coal was discovered in the Arbuckle Mountain area by Hezekiah Tippet, who located coal on Johnson Creek in 1878 or 1879 (Allen, 1947). This deposit was extensively prospected by the Blue Mountain Coal Company and the Arbuckle Company (a subsidiary of Union Pacific Railway). Allen (1947) reported that numerous cuts, three tunnels, a 45-ft (14-m) shaft, and a 950-ft (290-m) diamond-drill hole explored three coal beds at this property, which supplied several wagon loads of coal to Pendleton. According to Allen (1947), the uppermost bed was 42 in. (107 cm) thick and was separated from a middle bed of unreported thickness by 30 ft (9.1 m) of sandstone. The middle and lower seams were separated by a thin bed of black shale that contained numerous leaf impressions and a 70-ft (21.3-m) -thick section of sandstone. The coal beds reportedly were similar in character and were comprised primarily of nonfissile carbonaceous shale (bone). Allen (1947) reported that, where exposed in one short tunnel, the lower bed consisted of, from top to bottom, 6 in. (15.2 cm) of coal, 60 in. (152 cm) of carbonaceous shale, and 24 to 36 in. (61 to 91 cm) of bony coal.

The most extensive work in the area was done by the Heppner Coal Company on the Willow Creek prospect, which was discovered by William Herron in the 1880's. Total development work on the Willow Creek prospect consisted of six tunnels having a total length of 2,400 ft (731 m) and two diamond drill holes with vertical depths of 620 and 625 ft (189 and 190 m), respectively (Collier, 1914). According to Morrison (1939), 50 tons of coal were sold in Heppner from this property. All workings were caved when the area was visited by Allen in 1947 and by the writers in 1985. Mendenhall (1907) reported that the tunnels were probably on a single coal bed, which was about 53 in. (135 cm) thick in the No. 4 tunnel. The bed reportedly consisted of thin lenses and seams of "bituminous coal" interbedded with bone. The coal bed varied in thickness and was overlain and underlain by sandstone (Mendenhall, 1907). Morrison (1939) noted that the Heppner Coal Company reportedly drilled a diamond-drill hole near the south quarter corner of sec. 4, T. 5 S., R. 28 E., that intersected a 38-in. (97-cm) -thick coal bed at less than 300 ft (91 m) in depth. Collier (1914) reported the following analysis furnished by the Heppner Coal Company:

%Moisture	%Volatile matter	%Fixed carbon	%Ash	%Sulfur
1.85	41.86	47.29	8.30	0.82

Collier (1914) further states: "It seems clear to the writer that such an analysis cannot be obtained from samples which are representative of the bed as a whole, but represent only picked samples from small stringers of pure coal."

The Clarke prospects, located in sec. 19, T. 4 S., R. 29 E., were actively prospected in the early 1900's and in the late 1930's. The workings include the 173-ft (53-m) Point Tunnel and a number of short drifts (Allen, 1947). Allen measured the following section near the portal of the Point Tunnel:

	In.	Cm
Sandstone..................	72	183
Bony coal, sandstone........	24	61
Sandstone, massive..........	12	30
Bony coal..................	72	183

COAL OCCURRENCES

A number of lignite coal beds have been exposed in recently constructed logging roads between Johnson Creek and Butter Creek. At least two separate coal beds are exposed along Forest Service Road 5730 near the south boundary of sec. 21, T. 4 S., R. 29 E. A 54-in. (137-cm) -thick coal bed at H-15 strikes N. 75° E. and dips 32° S.

Section at locality H-15, sec. 28, T. 4. S., R. 29 E.

	In.	Cm
Sandstone (gray, friable)		
Shale......................	--	--
Coal.......................	6	15
Shale with coal partings....	--	--
Coal.......................	4	10
Shale with coal partings....	--	--
Coal.......................	4	10
Shale with coal partings....	--	--
Coal.......................	3	7.5
Sandstone (fine-grained).........	--	--
Total thickness of coal-bearing bed	54	137
Total thickness of coal..........	17	42.5

A 3-ft (91-cm) -thick lignite bed is exposed at the H-16 locality.

Section at locality H-16, SW¼ SE¼ sec. 21, T. 4 S., R. 29 E.

	In.	Cm
Sandstone		
Clay........................	4	10
Coal........................	8	20
Clay........................	4	10
Coal*.......................	20	51
Sandstone...................	--	--
Total thickness of bed...........	36	91
Total thickness of coal..........	28	71

*Analyzed sample in Table 1

Several coal beds are also exposed along the Kinzua Logging Company road in secs. 15, 16, and 17. A 3-ft (91-cm) -thick bed is exposed at the H-26 locality.

Section at locality H-26, SW¼ SW¼ sec. 20, T. 4 S., R. 29 E.

	In.	Cm
Shale and clay		
Carbonaceous shale...........	--	--
Coal........................	12	30
Shale and clay with coal partings...................	24	61
Siltstone...................	--	--
Total thickness of bed...........	36	91
Total thickness of coal...........	12	30

Three separate coal beds are exposed along a series of road cuts at the H-27 locality. On the south side of a small draw, the sequence is capped by laminated gray sandstones.

Section at locality H-27, NE¼ SE¼ sec. 16, T. 4 S., R. 29 E.

	In.	Cm
Sandstone, laminated		
Clay........................	8	20
Coal........................	10	25
Clay with coal stringers.....	36	91
Shale.......................	36	91
Andesite porphyry................	--	--
Sandstone........................	36	91
Shale............................	60	152
Coal........................	12	30
Shale with coal partings.....	60	152
Sandstone........................	24	61
Shale with coal partings.....	--	--
Base not exposed		

The thickest coal bed encountered is exposed at locality H-20 on the north side of Johnson Creek in NE¼ sec. 17. Here a 7-ft (2-m) -thick bed of coal and siltstone strikes N. 45° W. and dips 35° to the north. The bed is interrupted by an andesite porphyry dike and consists of lenses and seams of black coal up to 2 in. (5 cm) thick. The coal bed overlies a sequence of 6- to 12-in. (15- to 30-cm) -thick, fine- to medium-grained sandstone beds that are separated by siltstone lenses and partings.

DEPOSITIONAL ENVIRONMENT AND PROVENANCE

The association of cross-bedded sandstones and interbedded sandstone, siltstone, and lignite deposits indicates that the Herren formation was deposited in a proximal deltaic environment (Shorey, 1976; Elmendorf and Fisk, 1978; Fritts and Fisk, 1985).

Coarse detritus from metamorphic rocks and quartz diorite in the basal member of the Herren formation (unit $\mathbf{Th}_1$) was apparently derived from the underlying basement complex. Some of the potassium feldspar and muscovite in the Herren formation probably was derived from the distant highlands in which potassium feldspar and white mica were major constituents of the rocks. The location of such source areas is questionable. None of the rocks presently exposed in northeast Oregon appear capable of supplying the necessary concentrations of these minerals. Based on isotopic data, Heller and others (1985) suggested that the source area might have been the two-mica granites of the Idaho Batholith. If so, the potassium feldspar and muscovite may have been transported by river channels that cut through or around the Blue Mountains and drained the Idaho Batholith region. An alternative source might be the two-mica granitic rocks in northern Washington.

The significance of the porphyritic andesites in the Johnson Creek and East Birch Creek areas is not well understood. The absence of lithic representation of the volcanic rocks in the adjoining sandstones indicates that volcanic rocks were not a part of the sandstone provenance at that time. If some of the volcanic rocks are flow rocks, they probably were erupted from local vent areas and rapidly buried by subsequent sand layers. The presence of lithologically similar intrusives in the Johnson Creek and East Birch Creek areas suggests emplacement from local vent areas.

Our work indicates that the upper member (member **Th**$_3$) of the Herren formation in the Johnson Creek area contains feldspathic arenites comprised primarily of quartz, potassium feldspar, and muscovite. The selective concentration of these more stable grains indicates that member **Th**$_3$ contains more mature sandstones than do the underlying members. Presumably as the basin into which the Herren formation was being deposited developed, the less stable mafic mineral and plagioclase grains were being destroyed by progressive cycles of reworking.

The lack of metamorphic and volcanic detritus in member **Th**$_3$ suggests that the basement rocks in the immediate area had been buried by this time. Certainly there could not have been a nearby highland of pre-Tertiary or Tertiary volcanic rocks. The only volcanic components in member **Th**$_3$ are presumably air-fall tuffs.

Fritts and Fisk (1985) suggest that the Columbia Plateau is underlain by a rift-related basin that began to form in Early Cretaceous time and that the Herren formation represents part of the sediment that accumulated in the basin. They note the lithologic similarity of the Herren formation to coeval rocks in the North Cascades of Washington (specifically the Chuckanut Formation and possibly the lower part of the Swauk Formation). These concepts lead to the speculative idea that the Herren formation is coeval with part of the Paleogene section of central Washington and that Paleogene arkosic sandstones may be widespread beneath the basalt of the Columbia Plateau.

REGIONAL CORRELATIONS

Thick sequences of Eocene arkosic sandstones are erratically exposed throughout western Oregon and central Washington. The thickest sections are in central Washington, where the Swauk, Chuckanut, Chumstick, and Roslyn Formations are exposed. According to McKee (1972), the Swauk Formation is at least 23,000 ft (6,900 m) thick in the vicinity of Leavenworth, Washington. The Roslyn Formation is about 6,000 ft (1,800 m) thick and consists primarily of thick, fluvial arkosic sandstones. The upper part of the Roslyn Formation is noteworthy in that it contains five formerly productive bituminous coal beds (Beilkman and Gower, 1966).

The Tyee Formation in southwestern Oregon attains a thickness of about 7,000 ft (2,100 m) and contains a substantial arkosic component. Heller and others (1985) present isotope data that suggest that white mica and potassium feldspar grains in both the Tyee Formation and Herren formation were derived from two-mica granites, possibly either the Idaho Batholith or granite in northeastern Washington.

Scattered exposures of continental sedimentary rocks elsewhere in northeast Oregon suggest that the Herren formation may be laterally extensive to the north and south of the Blue Mountain uplift. Paleocene to Eocene arkosic sandstones in the East Birch Creek area southeast of Pendleton are considered to be equivalent to the Herren formation (Pigg, 1961; Shorey, 1976; Gordon, 1985). Collier (1914) reports a great thickness of sandstone, shale, and conglomerate resting upon serpentine and underlying tuffs south of the Blue Mountain anticline near Mt. Vernon in Grant County. Walker (1973) shows similar arkosic sandstones extending to the southwest near Wetmore in Wheeler County. Fritts and Fisk (1985) note that the Texaco 1 Federal exploration well south of Mitchell in Crook County penetrated 700 ft (210 m) of late Cretaceous to Paleogene strata containing quartzose sandstones that may be equivalent to the Herren formation.

COAL POTENTIAL

The coal-resource potential in the Arbuckle Mountain coal field is regarded as low due to the following factors: (1) Although individual coal beds as much as 7 ft (2 m) thick have been found in the area, the amount of usable coal in any one bed is relatively small. Mendenhall (1907) noted, "The coals thus far revealed by developments are not usable in the ordinary commercial way because of their very high percentage of ash due to the intimate intermingling of coal and bone." Individual coal beds are normally comprised of numerous narrow coal seams that rarely attain over a few inches in thickness. Not more than 40 percent of an individual coal bed is comprised of pure coal. (2) A bulk sample of the thickest observed seam (H-15) in the Johnson Creek area indicates that the coal is a black lignite that yielded 7,424 Btu per lb on a moist, mineral-matter-free basis (Table 1). Under current economic conditions, lignites are considered as coal resources only when occurring in seams 64 in. (163 cm) or greater in thickness. (3) The known coal beds are laterally discontinuous and have been interrupted by faulting and by emplacement of andesite porphyry masses. (4) The Arbuckle Mountain coal field lies along the core of the Blue Mountain uplift and has been folded and faulted, making it impossible to follow individual coal beds for any significant distance. Previous mining attempts were repeatedly frustrated by displacement of the coal beds.

Minable quantities of coal may exist within the Herren formation outside of the Arbuckle Mountain coal field. Subbituminous coals have been mined in the past from deposits associated with continental arkosic sandstones of similar age in the Roslyn Formation in Washington and the Coaledo Formation in western Oregon.

TABLE 1. Proximate analysis*

	As received	Dry basis
% Moisture	26.37	--
% Ash	22.88	31.08
% Volatile	24.64	33.47
% Fixed carbon	26.11	35.45
	100.00	100.00

MAF*** Btu/lb	11021
% MAF volatile	48.56
% MAF fixed carbon	51.44
Lb. sulfur dioxide/million Btu	1.50
% Air-dry loss	8.18
Moist, mineral-matter-free Btu/lb	7424**
% Dry, mineral-matter-free volatile	46.50
% Dry, mineral-matter-free fixed carbon	53.50
Lb. sulfur/million Btu	0.75

* Analyzed by Commercial Testing and Engineering Co.

** Based on as-received moisture

*** MAF = Moisture and ash free

OTHER POTENTIAL RESOURCES

The continental arkosic sedimentary rocks of the Herren formation appear to have a potential to host other mineral or energy resources. Fritts and Fisk (1985) conclude that the Herren formation has excellent oil and gas source and reservoir potential. Law and others (1984) present data from two samples from the Willow Creek area (082 TF-15 and 082 TF-14) indicating that sandstones in the Herren formation are marginally mature with respect to natural-gas generation and have a moderate source-rock potential. The friable quartz arenite sandstones in the upper part of the Herren formation may be the best potential reservoir rocks in the entire unit. The Herren formation as a whole is matrix poor. Study of the permeability and porosity of the sandstones appears warranted.

Several areas of hydrothermal alteration were noted during reconnaissance geologic mapping by the authors. The most extensive alteration zone is located on the southeast flank of Madison Butte. This locality was visited because it was reportedly one of the early sites of coal discovery in the Heppner area. The prospect pits were dug in highly iron-stained and silicified clastic rocks. The host rocks are presumably volcaniclastic rocks in which relict chalky feldspars are surrounded by silicified groundmass.

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