AN ABSTRACT FOR THE THESIS OF

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Title: STRATIGRAPHY OF THE BURNS JUNCTION-ROME AREA, MALHEUR COUNTY, OREGON

Abstract approved Redacted for Privacy
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Over 2500 feet of Late Tertiary continental volcanic rocks and interbedded sediments are exposed in the Burns Junction-Rome area. The oldest rocks within the area are Miocene andesites which exhibit abundant flow-breccia structure. Lying disconformably on the andesites are spherulitic rhyolite rocks. Disconformably on the rhyolite are Pliocene (?) lower basalts that built up to considerable thicknesses within the area. Younger basalts are thin (25-40 feet) and are associated with fault-controlled cinder cones and vents. All the basaltic rocks examined are of the high-alumina type, generally with a vesicular texture.

Depositional environments represented in the Rome area include fluvial, shoreline lacustrine, lacustrine and aeolian (?). The sediments are dominantly tuffaceous mudstones, siltstones, and wackes with associated vitric tuffs. Consolidation varies from semi-

to well-consolidated in the Miocene and Pliocene rocks, to generally poorly consolidated in the Pleistocene units. Lithic pebble conglomerates and pebble to cobble gravels occur as lenses and beds within the sediments. The quartzite, chert, and intruded volcanic lithic clasts indicate a deformed geogynclinal sequence was providing clasts during middle Pliocene and Pleistocene times. Based on 73 cross-bedding measurements the source area for this geosynclinal debris during the middle Pliocene probably was north or west of the Rome area. During the Pleistocene it is believed that the Owyhee River provided quartzite and chert from terrain south of Rome in Nevada.

Structurally the area is part of the Basin and Range province, although the characteristic block faults so prevalent to the south and west do not occur here. Gentle folding of the area during the Pliocene and Pleistocene (?) resulted in the development of localized basins which received up to 500 feet of sediments.

Zeolites make up the only economic deposit of potential within the map area. Extensive claims in the "Rome beds" are being maintained to date by a mineral exploration company.

Stratigraphy of the Burns Junction-Rome Area,
Malheur County, Oregon

by

Bruce Edward Ellison

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INTRODUCTION

Location and Accessibility

The area investigated is located in the Owyhee Upland province of southeastern Oregon, approximately 100 miles southeast of Burns (Plate 1). Steens Mountain lies approximately 40 miles west of the area, and the Owyhee Mountains are 40-50 miles to the east and southeast. This area includes all of T. 31 S., R. 40 E., secs. 1, 3, 10-15, 19-36, T. 31 S., R. 41 E., and the northern half of T. 32 S., R. 40 E. The small village of Rome is situated along the north-flowing Owyhee River in the eastern part of the mapped area. Crooked Creek joins the Owyhee River in the northeastern part of the map area.

Year round access to this area is provided by U.S. Highway 95 from the south and the east, and by Oregon State Highway 78 from the northeast. From Rome, graveled secondary county roads provide access to the northern and eastern parts of T. 31 S., R. 40 E. Elsewhere low relief and scanty vegetation permit access by 4-wheel drive vehicles. As a consequence, hiking distances to any outcrop rarely exceed one-quarter mile.

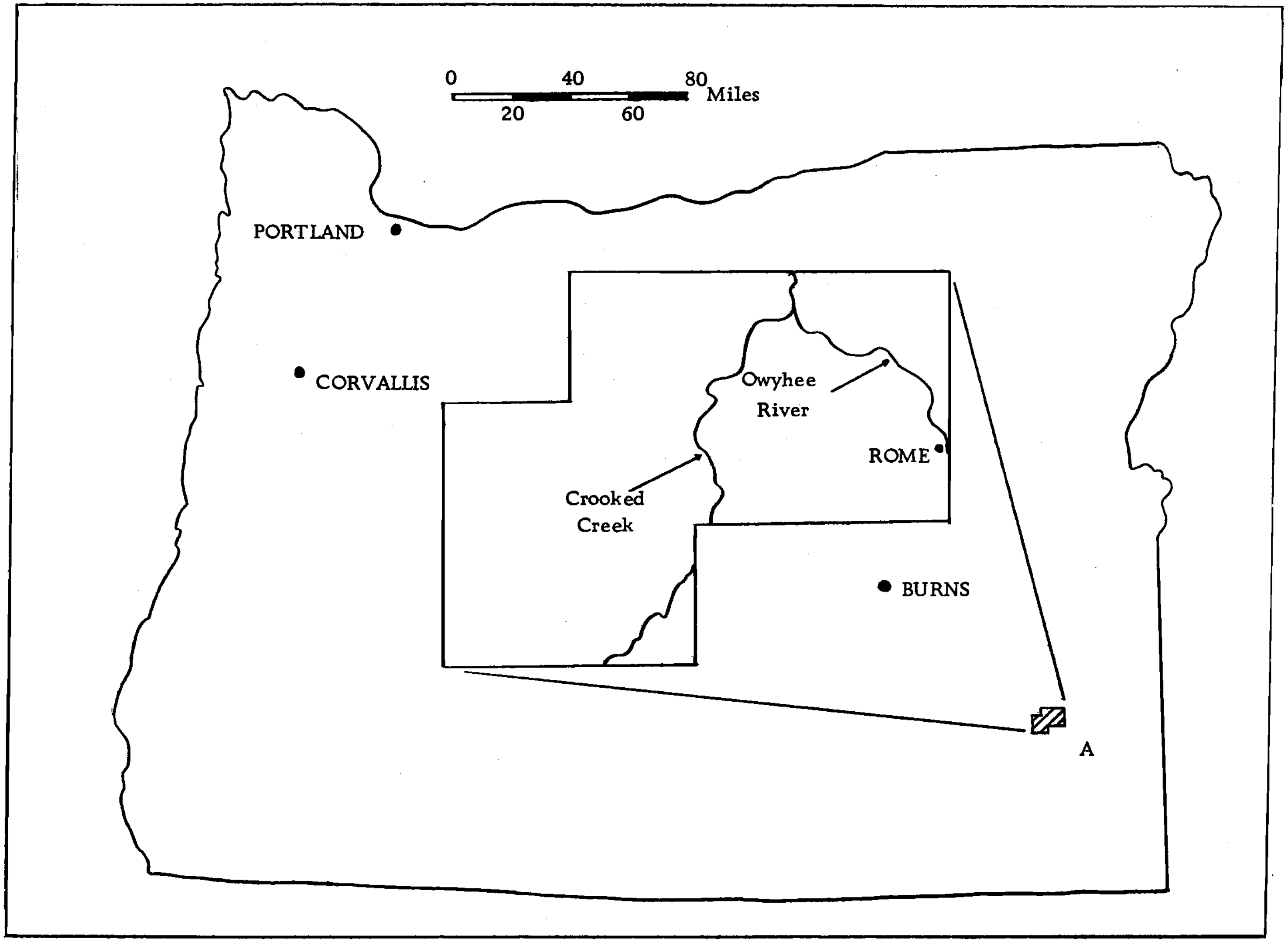

Plate 1. Index map of Oregon showing location of thesis area.

Purposes and Methods of Investigation

The primary objectives of this investigation were: (1) to map the surface geology of the area; (2) to measure and describe the exposed sedimentary section; (3) to determine paleo-depositional environments that existed during "Rome" sedimentation.

Field work began on August 1, 1967, and was completed on October 7, 1967. The surface geology was plotted on high altitude (1:60,000) aerial photographs obtained from the U.S. Geological Survey and was transferred to planimetric maps of the Bureau of Land Management.

Rock unit thicknesses were measured directly using a tape or by hand leveling with a Brunton compass. Attitudes of foreset cross-laminations within the "Rome beds" were measured and a rosette diagram (Figure 9) was prepared to determine paleocurrent flow patterns. Thirty-five thin sections were prepared from selected samples and studied microscopically. Field lithologic descriptions were made with a 10x hand lens.

The classification of sandstones followed in this report is that of Gilbert (Williams, Turner and Gilbert, 1958). The argillaceous sedimentary rocks are classified according to Folk (1965).

Previous Work

Russell (1903) first made note of the geology in this area when he mentioned that rain-sculptured lacustrine sediments occurred along the Owyhee River near Jordan Creek. Wilson (1935) described a new species of beaver (*Dipoides stirtoni*) from the sediments near Rome, and in 1937 Wilson published on the Rome fauna, a collection of Hemphillian vertebrate fossils from the same area.

Recent work includes that of Wheeler and Cook (1954), who postulated that the Snake River flowed through the area in Plio-Pleistocene times, and Walker and Repenning (1966), who mapped the east half of the Jordan Valley quadrangle. The latter map includes the area investigated, but is on a small scale (1: 250, 000).

Shotwell (1963) has discussed the paleoecology of the Juntura Basin, approximately 60 miles to the north, which contains a similar sequence of rock units.

Landscape Characteristics

Elevations within the area range from slightly less than 3, 400 feet in the north along the Owyhee River to 4, 200 feet at Scotts Butte in the west.

Generally the area is one of basalt benches in the west and sedimentary benches and scarps in the east (Figure 1). The sedimentary scarps have been extensively weathered into hoodoos and badlands.

The north-flowing Owyhee River and Crooked Creek provide the only important perennial drainage for the area (Plate 1). Crooked Creek emerges from springs within its dry bed near the southern boundary of the area. The Owyhee flows through the area to join the Snake River just north of Adrian, Oregon. Intermittent streams flow into these two during the spring and summer storms.

Natural vegetation consists of several species of sagebrush (*Artemisia*), rabbit brush (*Chyrosothamnus*) and other hardy small shrubs and grasses that can survive the rigorous climate. Cottonwood (*Populus angustifolia*) and other large shade trees have been planted and maintained by man in very local areas.

Rock exposures are good where streams have been able to carry away weathered debris; however, in the upper reaches of dry washes and canyons alluvium covers or partly conceals contacts. Sedimentary outcrops are exceptionally good in the vertical to nearly vertical cliffs northwest of Rome.

Climate

The U.S. Weather Bureau maintains a station at Danner, 16 miles to the east of Rome, and makes estimations for Rome, thereby providing approximate climatological data for the thesis area.

Figure 1. View from eastern map area looking west. Flat surface on horizon is formed by Qb basalts. QTba basalts form a discontinuous dark line in upper right below Qb surface. "Rome beds" in both the foreground and center weather into hoodoos and badlands topography.

The mean annual temperature within the area is 46.6°F. January is the coldest month, with temperatures often falling below 0° F. July is the warmest month, with highs above 105°F. Approximately 100 days are frost-free in a normal year.

The area receives from 9 to 11 inches of precipitation per year, with maximum precipitation occurring during the winter and spring months. Rainfall during the summer months is restricted to localized, frequently violent, thunderstorms that function as important agents of erosion.

STRATIGRAPHY

Stratigraphy of Adjacent Areas

This discussion of the regional stratigraphy will be limited to parts of the Snake River Plain approximately 90 miles east of the thesis area, to the Steens-Mountain-Trout Creek Mountains 40 to 60 miles to the west and southwest, to the Juntura Basin 60 to 70 miles to the north, and to the area which is bounded on the south by the Basin and Range region along the Oregon-Nevada border. The section exposed is made up almost entirely of Cenozoic volcanic and detrital rocks of continental origin.

In the Snake River Plain, Malde and Powers (1962) have described a series of volcanic and sedimentary rocks which they have subdivided into unnamed rocks of Miocene age, the Pliocene Idavada Volcanics, the Plio-Pleistocene Idaho Group, and the Pleistocene Snake River Group. According to Lindgren and Drake (1904) the granite of the Idaho batholith crops out through the unnamed rocks of Miocene age and Idavada Volcanics, both of which are exposed in the Owyhee Mountains between the thesis area and the Snake River Plain. The Idaho and Snake River Groups represent lacustrine-fluvial deposits and interbedded lava flows deposited in a downwarped area between the Owyhee Mountains and the Idaho batholith. Malde and Powers (1962, p. 1202) give a composite thickness for the Idaho Group of over 5, 000 feet, but they note that the thickness at any specific locality is considerably less because of erosion and local thinning. The Snake River Group has a composite thickness of 900 feet.

Near the base of Steens Mountain, Fuller (1931) described and applied the name Alvord Creek beds (Formation) to over 800 feet of well-stratified, in part water laid, "tuffs." These "tuffs" are considered by Fuller (1931, p. 5) to be Miocene, probably correlative with the Mascall Formation in the John Day Valley farther north. This age assessment is based on floral material, however, and Axelrod (1957, p. 24-25) gives a Pliocene age for these beds. The Alvord Creek Formation interfingers with and is overlain by 1500 (?) feet of laminated rhyolites and tuffs of the Pike Creek Volcanics. This unit is overlain in turn by the 1500 feet of basalt and andesite flows that make up the Steens Mountain Volcanic "Series." This poorly-stratified unit is overlain by the well-stratified, columnar flows of the Steens Mountain Basalt, which is up to 3, 000 feet thick. Smith (1927, p. 428) tentatively correlates the Steens Mountain Basalt with the Columbia River Basalt. Fuller (1931, p. 114) believes that the Steens Mountain Basalt is correlative with the Pueblo Mountain "Series" to the south, and that both units are younger than the Columbia River Basalt. Baldwin

(1964, p. 131) agrees with Fuller and cites a similar vertical sequence in the Sucker Creek area along the Idaho border. This would indicate a late Miocene age for the Alvord Creek Formation, making the beds above younger than the Columbia River Basalt.

In the Trout Creek Mountains southeast of Steens Mountain crop out the leaf-bearing late Miocene diatomaceous sediments of the Trout Creek Formation (dated by MacGinitie, 1933). This area evidently was a highland during outpourings of the Steens Mountain Basalt, for these flows lap against but fail to cover the Trout Creek Formation (Baldwin, 1964, p. 132).

North in the Juntura Basin, Shotwell (1963) considers the rocks exposed to be divisible into a "basement complex," the Juntura Formation, the Drewsey Formation, the Drinkwater Basalt, and an unnamed rhyolite intrusive. The "basement complex" consists of 125 feet of welded tuff overlain by approximately 1500 feet of olivine basalts. Overlying this unconformably are 1200 feet of dominantly tuffaceous, diatomaceous sediments making up the Juntura Formation. The uppermost Juntura beds contain mammalian fossils indicative of Clarendonian age (Shotwell, 1963, p. 28). The Hemphillian Drewsey Formation, another tuffaceous sedimentary unit, lies unconformably on the Juntura Formation. Maximum thickness of the Drewsey Formation is 1,000 feet. All of the beds have been affected by folding which has resulted in a northwest-trending anticline whose beds dip more steeply to the west. The Plio-Pleistocene Drinkwater Basalt, 25-30 feet thick, is nearly horizontal upon the lower inclined beds. Dr. K. F. Oles (personal communication) suggests the Drinkwater Basalt may possibly be a correlative of the Ochoco Basalts and Madras Lavas. The unnamed rhyolite is a large dome-like intrusive that apparently has been locally extruded over the surface of the basalt. Kittleman et al. (1967) have extended several of the above units south towards the thesis map area.

The Cenozoic rocks present progressively fewer outcrops of sedimentary rocks toward the Nevada border. Of interest, however, is the Paleozoic section exposed by normal faulting in northwestern Elko County, Nevada. This area carries the headwaters of the present-day Owyhee River. Granger et al. (1958, p. 10) present a composite measured section in this area of 3, 600 feet of limestone and quartzite beds of Middle Ordovician through Devonian age. The basal unit is in the Eureka Quartzite, made up of 1, 500 feet of very light gray to white, medium-grained quartz arenite whose grains are well sorted and rounded. Quite possibly this quartzite has furnished clasts for the Pleistocene gravels in the Rome Area.

Thesis Area Stratigraphy

The rock distribution within the map area is generally one of volcanic rocks in the west and north with sedimentary rocks dominating to the east and south (Plate 2).

Extrusive igneous rocks range from rhyolite to basalts, with a general increase in calcic plagioclase- and olivine-bearing rocks through time. Much of the olivine in the basalts has been converted to iddingsite. Textures vary from diky taxitic vesicular basalts to intersertal vesicular andesite and spherulitic rhyolite. The basalt in places exhibits a granular texture, possibly as a result of flowing into water or because of weathering or both. Structures in the rhyolite vary from massive to columnar, with locally abundant spherulite zones. The basalts are usually columnar, but some are massive and a few are platy. The andesite exhibits flow-breccia structures.

The sedimentary rocks are dominantly tuffaceous. Aeolian and fluvial processes were responsible for transportation to depositional sites. The depositional sites included both fluvial and lacustrine environments, the rocks of which are in intricate interfingering relationships where well-exposed. Sedimentary structures such as graded bedding, cross-bedding and ripple marks are also well exhibited at several localities.

In stratigraphic sequence, the lowest stratigraphic unit consists of Miocene andesite flow rocks, Taf (Figure 2). Unconformably above the andesites are rhyolite flows, (Trf). These rhyolites are overlain unconformably by pumiceous volcanic wackes, (Trs). Two

Age	Informal unit	Symbol
Pleistocene	Upper basalt flow	Qb
	Upper sediments (mudstones, silts and gravels)	Qs
	Intracanyon basalt flows	QTba
?		
Pliocene	Unnamed sedimentary rocks (sands and wackes)	QTs
	"Rome beds" (siltstones, wackes and conglomerates)	Tst
?	Lower basalt flows	Tb
Miocene	Rocks of mafic vents	Tmv
	Scoriaceous volcanic wacke	Tvs
	Rocks of mafic vents	Tmv
	Pumiceous volcanic wacke	Trs
	Rhyolite flow rocks (base not exposed)	Trf
	Andesite flow rocks (base not exposed)	Taf

Figure 2. Chart showing stratigraphic sequence of major units and their map symbols.

Miocene (?) - Pliocene units - the rocks of mafic vents (Tmv) and their interbedded scoriaceous volcanic wackes (Tvs) - are of uncertain stratigraphic position. They are treated in this report as lying below the lower basalt flows (Tb). These lower basalt flows are overlain with angular unconformity by the mid-Pliocene "Rome beds" (Tst). An unnamed Plio-Pleistocene lacustrine-fluvial sedimentary unit (QTs) overlies the "Rome beds." This sedimentary unit (QTs) is overlain in turn by intracanyon basalt flows (QTba) that interfinger with and are overlain by the uppermost (Pleistocene) lacustrine-fluvial sedimentary unit (Qs). These sediments are overlain by the upper basalt flows (Qb). Upon the Qb and QTba basalts playa deposits are developed. The stream valleys contain terrace deposits and recent alluvium.

Miocene Units

Andesite Flows (Taf). The oldest rock in the map area is andesite, which crops out only in secs. 16 and 17, T. 32 S., R. 40 E., (Plate 2). To the west and south this andesite crops out extensively in the Bowden Hills and on Flattop Mountain (Walker and Repenning, 1966). Outcrops within secs. 16 and 17 are very poor, limited to rare ledges and limited exposures along intermittent stream beds.

No basal contact is exposed, but exposures to the south and west indicate thickness of the unit must be at least several hundred feet. On fresh exposures the andesite is a grayish red purple (5RP 4/ 2) and weathers to a pale red (5R 6/2).

The following rock component percentages were established by petrographic means: 53-58% groundmass, 15% plagioclase phenocrysts, 20-25% vesicles and 7% magnetite and hematite. The groundmass is composed of 25% magnetite needles partly altered to hematite and 70-75% fine plagioclase laths with minor (up to 5%) glass. The plagioclase laths have been altered to calcite and an unidentified fibrous zeolite (?) around some vesicles. The phenocrysts of subhedral plagioclase (An_{48} by the Michel-Levy method) have a maximum dimension of 1.25 mm. with many crystals exhibiting albite twinning. The subhedral to anhedral magnetite grains have a maximum length of 0.75 mm, and have been altered in part to hematite.

Microscopically the texture varies from pilotaxitic to intersertal. The abundance of vesicles and their shapes vary throughout the andesite. Many of these vesicles are concentrated in one to two inch thick bands four to eight inches apart. Evidently after this concentration movement took place within the flows, for vesicles are flattened and drawn out in a horizontal plane with pointed terminations. Some outcrops exhibit platy angular andesite fragments up to five inches long incorporated in a groundmass of andesite. This may again represent flowage within a semi-consolidated mass resulting in a flow-breccia.

The basal contact of this unit is not exposed. The andesite is unconformably overlain along the western contact by the uppermost basalt flows (Qb, Plate 2) whereas to the north and east the andesite is lapped disconformably by Miocene (?) pumiceous volcanic wackes (Trs, Plate 2). Because of poor outcrops contact relationships are obscured and at no one locality is the sedimentary-volcanic contact well shown.

Walker and Repenning (1966) correlate the andesite in part with the Steens Mountain Volcanic "Series" to the west. To the north the unnamed igneous complex of Kettleman et al. (1967) is a probable correlative. Very likely the andesite is correlative in part with the unnamed volcanic sequence of Malde and Powers (1962) in the Owyhee Mountains.

Rhyolite Flow (Trf). Restricted to secs. 4, 5, 8, 9 and 16, T. 31 S., R. 41 E., the rhyolite flow rocks are well exposed at the confluence of Crooked Creek and the Owyhee River. For a distance of two miles upstream along Crooked Creek and three miles downstream along the Owyhee from this junction, the rhyolite crops out in precipitous cliffs ranging from 50 to 300 feet high (Figure 3). Away from these cliffs the rhyolite outcrops are either covered by sediments (as erosional effectiveness drops off); or, as along the

Figure 3. Rhyolite flow rocks (Trf) exhibiting semi-circular to vertical jointing. Owyhee Canyon.

Owyhee River near the northern map limit, they are covered by later basalt flows right up to the canyon rim. Except where exposed by actively eroding streams, the outcrop pattern is one of overhanging ledges 10-50 feet long that protrude one to three feet above a rubble-strewn substratum of rhyolite debris.

Because the base of the rhyolite was not observed, total unit thickness could not be determined, but in the Owyhee River canyon at the extreme northern end of the map area over 200 feet of rhyolite is exposed in the canyon walls.

The color of fresh surfaces is pale purple (5P 6/2) to dusky red (5R 3/4), while weathered surfaces are pale pink (5RP 8/2) to dark reddish brown (10R 3/4). Vesicles vary in abundance from 10% to 40% by volume of the rock; they range in size from microscopic up to 75 mm in diameter. Spherulites with a maximum diameter of 50 mm are filled with cristobalite and feldspar, locally giving the rock a white mottled appearance. Phenocrysts of sanidine and quartz are abundant throughout the rock (up to 35%).

Thin section examinations established the following percentages in the rhyolite: 58-60% glass and vesicles, 22-25% sanidine, 15-18% quartz and 1-2% magnetite. The glass exhibits abundant extinction crosses associated with microscopic spherulites (crossed nicols), and flow patterns are outlined by crystallites (usage of Kerr, 1959) under plain light. Many larger spherulites are present which contain tiny radial aggregates and crystals of cristobalite and feldspar. The euhedral to anhedral sanidine crystals have a maximum diameter of three mm. The quartz is dominantly subhedral with dimensions similar to the sanidine. The magnetite crystals are subhedral to anhedral with a maximum width of 0.35 mm. No evidence is present for alteration of magnetite to hematite in the crystals; however, the glass shows some red coloration, possibly resulting from oxidation of iron.

Structures present include jointing and discontinuous lenses and tabular spherulite zones. The joints are well exposed in canyon walls where they form semi-circular to vertical fractures 24-36 inches apart sweeping across the entire cliff face. Locally these fractures cut the spherulitic zones at various angles. Moreover, the spherulite zones (two-four feet thick) lie at different angles to each other.

The basal contact of the rhyolite is not exposed within the area. However, in the Jordan Valley area, Walker and Repenning (1966) have mapped a rhyolite they consider correlative as overlapping the andesite unit (Taf) with slight angular discordance. Within the map area the rhyolite is lapped unconformably by the Miocene (?) tuffaceous sediments (Trs), the lower basalt flows (Tb), the "Rome beds" (Tst), the intracanyon basalts (QTba), and the Pleistocene sediments (Qs). The time involved between extrusion of the rhyolite and the deposition of the tuffaceous sediments (Trs) cannot be accurately determined, but erosion had produced subangular pebbles to small cobbles of rhyolite which are now incorporated in the basal sediments. The lower basalt flows (Tb) unconformably overlie both the tuffaceous sediments and the rhyolite. Field relationships indicate that the "Rome beds" probably covered the rhyolite, only to be removed prior to deposition of the upper sediments (Qs). These uppermost lacustrine-fluvial sediments are also disconformable upon the rhyolite. In the Owyhee Canyon the rhyolite is overlain unconformably by the intracanyon basalts (QTba).

One possible correlative of the rhyolite may be the Jump Creek Rhyolite of Kittleman et al. (1967). The stratigraphic position of the Jump Creek Rhyolite is unclear, but it does overlie the Miocene Sucker Creek Group in the lower Owyhee area.

Walker and Repenning (1966) correlate the rhyolite in the thesis area with the Canyon Rhyolite of Merriam (1910). They also have mapped correlative rhyolite and welded tuff units to the south that may be correlative in part with the Idavada Volcanics of Malde and Powers (1962).

Pumiceous Volcanic Wacke (Trs). Outcrops of this highly tuffaceous, partly pumiceous sediment are found in secs. 9, 10, 15-17, T. 32 S., R. 40 E., and in sec. 8, T. 31 S., R. 41 E. Exposures in T. 32 S. apparently are related to faulting and/or subsequent removal of the lower basalt unit (Tb) by erosion. Here the outcrops lie along the fronts of two northeast-dipping cuestas and also partially encircle the andesite unit (Taf). Between these two areas a shallow gully (Plate 2) is underlain by volcanic wacke (Trs) that has been faulted (?) and intruded by the lower basalts (Tb). The small outcrop in T. 31 S. also is associated with the lower basalts, occurring between the basalts and the rhyolite, Trf. Weathering of the unit in both areas characteristically produces gentle slopes or flat areas. Good exposures occur only where the wacke is visible because of sapping beneath a protective basalt, or where stream erosion is active.

Unit thickness in T. 32 S. cannot be determined because of the lack of bedding. If the volcanic wackes (Trs) dip to the east at the same rate as the unconformably overlying basalts (Tb), thickness would be on the order of 400-500 feet. This figure would agree with the general outcrop thickness of lithologically similar rocks to the east and south. In T. 31 S. thickness ranges from 0 to 30 feet.

In T. 32 S. the unit is dominantly a yellowish gray (5 Y 7/2 to 5Y 8/1) vitric tuff (restricted usage of Hay, 1952) with weathered surfaces of very light gray (N 8). Fluvial reworking of this tuff (thereby creating a volcanic wacke) has resulted in the local introduction of up to 10% of dominantly subangular pebbles of andesite (maximum diameter 0.50 inches). Bedding is not evident in this western area, but the wacke commonly is jointed. In several areas near U.S. Highway 95 and along the southern edge of the map area oxidation to a grayish orange (10YR 7/4) color has resulted from intrusion. A vertical dike (length 250 feet, width 10-14 inches) of grayish red (10R 4/2) iddingsite-bearing basalt is exposed in the same area. This dike strikes N. 30° E.

In T. 31 S. to the east, the volcanic wacke (Trs) has one half to three inch, normally graded, angular to subangular pebbles to cobbles of rhyolite composing up to 15% of the basal two feet of this unit. Pumice fragments range up to 10% of this rock viewed in hand specimen. Discontinuous five to eight inch beds are present which strike N. 75° W., and dip 8° south. The upper six to eight inches of wacke has been oxidized to a moderate red (5R 4/6) by the overlying basalts. Sorting of the wacke is poor in both Townships 30 and 31 South.

The vitric tuff was examined in thin section and the following percentages were obtained: 70% glass shards and broken crystals, 15% pumic clasts and 15% matrix. The glass shards and crystals are dominantly fresh, angular, and range up to 0.50 mm in length. The broken crystals are dominantly feldspar and quartz with very minor magnetite altered in part to hematite. The pumice clasts are clear under plain light with elongate thin vesicles. These clasts range up to four mm in size. The matrix is a clay which probably was derived from devitrification of silt-sized glass fragments. Most of the larger glass shards are remarkably fresh, especially when compared with those in the overlying Pliocene and Pleistocene beds.

Few distinctive textures were noted. The vitric tuff certainly has a fragmental texture. Structures are limited to small (0.50 inches) spherical pellets and irregular tubes composed of clay (?) minerals, and to the poorly expressed normal grading present in the eastern outcrop.

The basal contact in T. 32 S. is poorly exposed, while the upper contact is sharp, with the basalts (Tb) overlying the wackes with one to two inches of relief and little visible oxidation. In T. 31 S. the basal contact is irregular with up to seven inches of relief developed by erosional processes upon the underlying rhyolite at one outcrop. Here the upper contact has been deeply oxidized by the overlying basalts.

Farther south similar volcanic wackes are considered by Walker and Repenning (1966) to be Miocene. Dr. Arnold Shotwell has identified a jawbone in these beds as Canis sp. of middle Miocene to Recent age. These rocks do lie stratigraphically below the Hemphillian "Rome beds." Deposition of the unit was probably dominantly by aeolian processes. Indicative of this is the structureless nature of most of the unit and the fresh, angular nature of the clasts. That minor reworking by streams occurred in some areas is indicated by the subangular pebbles of andesite. However, a fluvial or lacustrine environment did predominate in parts of T. 30 S., as indicated by the basal rhyolite pebbles and cobbles and the amount of relief developed upon the underlying rhyolite (Trf). The deeply oxidized zone in the upper beds in the area probably is indicative of the presence of water either in or above the wacke at the time of the basalt outpouring.

Miocene (?)-Pliocene Units

Rocks of Mafic Vents (Tmv). These rocks are limited to two partly dissected volcanic cinder cones in the western map area (Plate 2). Scotts Butte, the larger of the two, stands more than 200 feet above the lapping basalt unit, Qb. The smaller cinder cone, which rises 120 feet above the basalt surface, occurs approximately one mile to the east. Except for several large flows associated with the Scotts Butte cone, these rocks weather into smooth slopes mantled with scoria and broken by minor semicircular to straight ledges of vesicular basalt or firmly welded scoria. The large flows have, where present, protected the underlying scoria from erosion, thereby resulting in the greater height of Scotts Butte.

Maximum unit thickness must be greater than 200 feet, for these rocks make up a constructional feature of this height. Lithologically the basalt is a medium bluish gray (5B 5/1) to dark gray (N 3) vesicular to scoriaceous basalt with red iddingsite-altered olivine phenocrysts making up more than 5% of the rock viewed in hand specimen. Weathered colors range from moderate red (5R 4/6) to very dusky red (10R 2/2).

A modal analysis of one of the basalt flow rocks provided the following percentages: 53% labradorite (An_{61}, Michel-Levy method), 12% olivine with extensive rim alteration to iddingsite, 18% augite, 12% vesicles, 5% magnetite. The labradorite occurs as small subhedral to euhedral twinned laths with a maximum size of 0. 80 mm in length and 0. 10 mm in width. The olivine and augite exist as subhedral to euhedral crystals, with maximum euhedral augite crystal width of 0.90 mm, and many much smaller (0. 05 mm) olivine and augite subhedral grains randomly scattered between the plagioclase laths. Vesicles range in size from one mm downward. The euhedral-subhedral magnetite crystals, many of which have ragged borders, have a maximum diameter of 0. 10 mm.

Microscopic texture of the basalt is fluidal, with the plagioclase laths showing distinct flow lineation. A scoriaceous texture is also present. Structures vary from massive within the three to eight foot thick flows, to columnar within the 20 foot thick flow. The flows occur interbedded with the scoria. The scoria is mainly in the 32-256 mm diameter range; however, in local areas, lapilli predominate. The scoria is firmly welded in place forming rounded knobs that may represent eroded spatter cones. Fault structures may be present, but the flow outcrops do not appear offset and in the readily weathered scoriaceous rocks surface expression of faults would not remain long.

No basal contact for this unit is exposed; it is concealed by the lapping uppermost basalt, Qb. There is no upper contact since the unit "skies out."

An age assessment for this unit is difficult to make because of the contact relationships. A silica glass bead test was performed with four samples, one from each of the stratigraphically separated basalts and one from the mafic vent unit. There was no distinguishing index of refraction which would permit correlation; in fact, the indices indicated a very similar chemical composition for all four samples (Dr. Edward Taylor, personal communication). Based on stratigraphic position of the scoriaceous volcanic wacke (Tvs, Figure 2) very tentative correlation may be made with the lower basalt, Tb. The mafic vent unit would represent then a local eruptive center active during one or more of the multiple outpourings of lower basalt (Tb).

Scoriaceous Volcanic Wacke (Tvs). This unit crops out mainly on the south and east flanks of Scotts Butte, where exposures are associated with faulting or erosion of the mafic vent rocks (Tmv). One other possible outcrop lies along Palamino Creek in the N. E. 1/4 sec. 10, T. 32 S., R. 40 E. (Plate 2). Good outcrops are limited to fault scarps (Figure 4) and to areas of active stream erosion. Topographic expression is generally that of rolling, almost featureless, slopes broken by infrequent fault scarps five to seven feet high.

Total unit thickness is unknown, although more than 75 feet of volcanic wacke (Tvs) is exposed in one slope on the east side of Scotts Butte. This 75 foot thick unit is overlain by a flow of the mafic vent unit (Tmv), but the base is nowhere exposed. Extensive faulting has affected the unit -- dip directions vary greatly from outcrop to outcrop. The rock weathers readily so that relationships between isolated outcrops are extremely difficult to discern. Therefore, total unit thickness cannot be stated accurately. Based on the limited areal extent of this unit, an estimate of thickness is 150-200 feet.

The rock on fresh exposure is a moderate olive brown (5Y 4/4), generally poorly indurated, volcanic wacke that contains up to 20% pebbles and cobbles. Weathered surfaces have a dark greenish yellow (10Y 6/6) color with local staining to a light gray (N 9) that indicates the presence of carbonate cement. The pebbles and

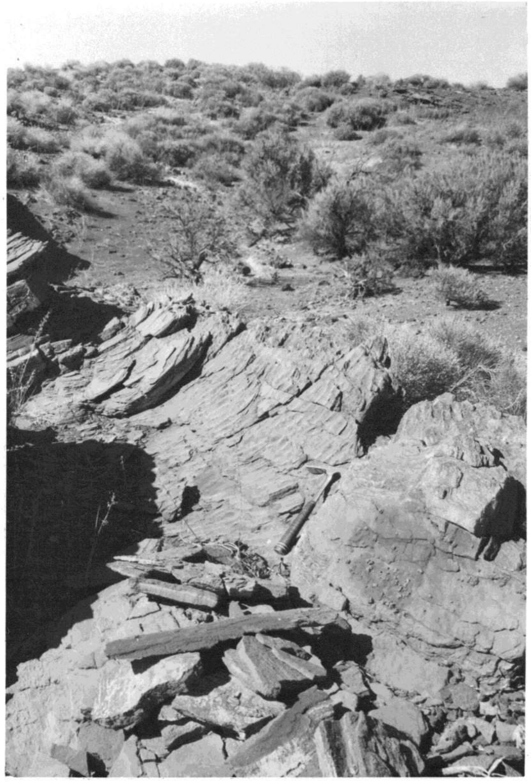

Figure 4. Fault scarp in scoriaceous volcanic wacke (Tvs), striking N. 80 W. Current ripple marks (near hammer) indicate transport from the west. Sediments are dragged up along the south block.

cobbles are dominantly angular and consist almost entirely of dark gray (N 3) scoria. All sizes of pebbles are present, and cobbles of up to eight inches diameter are locally plentiful (15%). The only outcrop where scoria does not compose 100% of the larger clasts is the Palomino Creek locality. Here, approximately 20% of the pebbles are sub-angular andesite derived from the Taf andesite unit.

Modal analysis of a calcite-cemented sample of the scoriaceous wacke (Tvs) provided the following percentages: sideromelane (basaltic glass) 75-80%, matrix 15-25%, calcite 1-10%, accessory olivine, augite, and plagioclase making up less than 1%. The sideromelane clasts are angular, range in size from 0.50 mm down to microscopic, with larger clasts exhibiting extensive rim alteration to pale green to yellow palagonite. The matrix is composed of sideromelane (?) fragments in the silt-clay-size fractions which have been altered locally to calcite. This calcite is rarely abundant enough to form an effective cement. The plagioclase crystal boundaries are corroded in part and altered to calcite, but the augite appears fresh. Carozzi (1960, p. 117) describes a similar alteration of sideromelane in what he considers the early stages of palagonitization.

This very immature rock is characterized by angular clasts, poor sorting, an unstable mineral assemblage, and abundant matrix. Sedimentary structures present include 6-24 inch thick planar bedding, cross-bedding, asymmetrical ripple marks (Figure 4), scour-and-fill channels and both normal and reverse graded beds. The scour-and-fill channels are up to 50 feet wide and 15 feet deep. The grading within the beds is best expressed in the four to six inch thick pebble zones.

Field observations indicate current transport from northwest to southeast. At the volcanic wacke outcrop along Palomino Creek the foreset beds indicate a more nearly west to east transport.

A basal contact is not exposed. The upper contact is well exposed only where protected by an overlying basalt flow. Here the contact is irregular with four to five inches of relief developed upon the wacke. There is no evidence of baking of the wacke by the basalt flow.

The age of this unit is not clear. Field evidence indicates the wacke interfingers with and is a correlative in part of the lower basalt flows. The wacke represents a water-laid deposit that resulted from reworking of the fragmental basaltic material ejected from the then active Scotts Butte volcanic center. Eruptions could have provided the water vapor for torrential downpours. These downpours and accompanying flash floods could account for the abundant fluvial sedimentary structures and also provide the necessary energy to move the large cobbles incorporated in the sediment.

Lower Basalt Flows (Tb). The lower basalt flows (Tb) crop out within the map area primarily in secs. 9-11 and 13-16, T. 32 S., R. 40 E.; however, there are subordinate outcrops in secs. 8 and 17, T. 31 S., R. 41 E. (Plate 2). Beyond the thesis area to the south and east, these basalts are well exposed in the Owyhee River canyon where they form either scarps or steep (20-30°) slopes. In T. 32 S. Crooked Creek cuts through east dipping flows that exhibit these topographic differences. Some of the flows are resistant to weathering and form steep gully walls, but others are poorly resistant, crumbling away into sloping walls. Under petrographic examination the poorly resistant flows are seen to be extensively altered, with the plagioclase being chloritized. Also traceable on Crooked Creek for short distances are orange pink (5 YR 8/4) 10-12 inch thick lenses of tuffaceous, partly baked, wackes to siltstone which are interbedded with the basalts.

Thickness of the unit is over 1000 feet. This figure was determined by assuming an average dip of 7° due east, an attitude obtained where the dipping basalts are lapped by the "Rome beds." Farther to the west these basalts (Tb) dip up to 9° east along fault-produced cuestas. Degree of dip and dip direction vary somewhat when taken on the interbedded sediments between the cuesta and the onlap, possibly indicating repetitions caused by concealed faulting.

The rocks on outcrop appear in two distinct habits. One is a highly vesicular grayish purple (5P 4/2) to grayish black (N 2) columnar basalt. The second habit is a massive to blocky, greenish black (5GY 2/1) basalt with less than 10% vesicles and a dominantly granular weathering texture. Sedimentary volcanic wackes and silt-stones containing angular to sub-angular pebbles and subordinate small cobbles of basalt and scoria occur as discontinuous 24-36 inch thick lenses between several of the flows. The color of the fresher parts of these sediments is pinkish gray (5YR 8/1).

Microscopic investigation of the two flow types indicates a similar gross composition. Both have approximately 12% olivine, with abundant iddingsite alteration, and 18% subhedral to euhedral augite crystals. In the greenish black flows the alteration to idding-site is almost complete. In the columnar jointed rock plagioclase is present as minute euhedral-subhedral laths of An_{60} composition (Michel-Levy method). The plagioclase in the granular textured rock is also in small laths, but these have been partly chloritized, resulting in a weak moderate yellow green (5GY 7/4) to light blue green (5GB 6/6) pleochroism. Minor calcite is a void-filler in the more vesicular resistant rock.

Texture of the basalt (Tb) is pilotaxitic and diktytaxitic, with some zones being quite vesicular (up to 35% voids). The chloritized basalts have a characteristic granular weathering texture which commonly makes them resemble sedimentary rocks on outcrop.

Structures range from massive to columnar to blocky. Associated with the granular textured flows are semi-rounded pillow-like structures up to 12 inches across, probably formed where the flows encountered small ponds or creeks.

The basal contact has been described where the pumiceous volcanic wacke (Trs) was examined (p. 20). Unconformably overlying the lower basalt flows (Tb) are the "Rome beds" (Tst), the intracanyon basalts (QTba), the Pleistocene sedimentary unit (Qs), and the upper basalt flow (Qb). the "Rome beds" overlie the basalts with an angular discordance of 3-9°. This contact has over 30 feet of relief in places, but is generally considerably less (Figure 5). The disconformity with the intracanyon basalt (QTba) is very difficult to determine; locally the disconformity must be based on a subtle weathering difference between the granular textured lower basalt (Tb) and the more resistant, horizontal intracanyon basalt. The Pleistocene sedimentary unit (Qs) at one time completely lapped the lower basalt, but in many areas in the southern map area only erosional remnants of Qs now overlie the basalts. The disconformity between the upper basalt (Qb) and the lower basalt (Tb) may be traced in the field by the presence of fresh olivine. Fresh olivine is characteristic of the upper basalt unit (Qb), whereas the lower basalts (Tb) contain iddingsite.

Extrusion of these basalt flows must have occurred episodically, with short intervals between outpourings during which local deposition of wackes and siltstones took place upon the flow surfaces. Short intervals of time are indicated because well-developed soil horizons are not present. The granular textured flows very likely were extruded upon a wet surface which aided in the chloritization of the plagioclase.

The age of the lower basalt flows (Tb) is questionable. The volcanic wackes (Trs) underlying the basalts are considered to be middle (?) to late Miocene (Walker and Repenning, 1966). Following extrusion of the lower basalts, extensive erosion and some deformation preceded deposition of the middle Pliocene "Rome beds"; therefore, the events that produced the lower basalt flows occurred in late Miocene or early Pliocene. Walker and Repenning (1966) correlate these basalts in part with the Idavada Volcanics. A likely correlative to the north is the basalt sequence of the Deer Butte Formation of Kittleman _et al_. (1967). Possible lateral correlatives within the map area are the rocks of mafic vents (Tmv) and the scoriaceous wacke (Tvs).

Pliocene Units

"Rome beds" (Tst). The "Rome beds" are a thick sequence of lacustrine-fluvial sediments that crop out mainly in secs. 1, 2, 4-24, 26-31, 33, 34, T. 31 E., R. 41 E. In T. 32 S., R. 40 E. they are limited to secs. 1, and 11-14; in T. 31 S., R. 40 E. there is a small outcrop in sec. 12. The "Rome beds" lap out on the lower basalt flows (Tb) in secs. 13-14, T. 31 S., R. 40 E. (Plate 2). From observations both north and south of the map area, it is evident that Rome sedimentation was restricted to areas roughly east of the point where the "Rome beds" presently pinch out.

Topographic expression is variously dependent upon the resistance of the unit overlying these sediments, the degree of induration of the sediments, and the erosional effectiveness of local streams. Where capped by basalts, and where erosion is rapid, the "Rome beds" form steep canyon walls. Where these sediments are overlain by other sedimentary units and erosion is fairly rapid, the Rome unit characteristically forms badlands topography (Figure 1). Locally, where erosion is not rapid the topography becomes subdued into smooth slopes of alluvium.

For this study the "Rome beds" are divided into lower and upper units. The criterion for this division is the presence of conglomerate beds and lenses within the lower "Rome beds" and their absence in the upper beds. Because of limited areal occurrence, and relative thinness, the upper Rome unit was not mapped separately (Plate 2).

Lower "Rome beds". Maximum thickness of the lower unit

Figure 5. Blocky weathering lower basalts (Tb) disconformably overlain by lower "Rome beds." The lighter sediments are wackes; the dark units are highly cross-bedded volcanic pebble to cobble conglomerates.

Figure 6. Reverse grading and a carbonate concretion in lower "Rome beds." Along Owyhee River.

exceeds 300 feet. This 300 foot thick section, with no base exposed, occurs in cliffs along the Owyhee River near the northeastern limit of the map area. Reconnaissance along Jordan Creek indicates the lower "Rome beds" continue to thicken towards the east, and may extend east for at least 30 miles (Walker and Repenning, 1966).

The rocks on fresh exposure are dominantly a grayish yellow green (5GY 7/2) to bluish white (5B 9/1) siltstone to mudstone with interbedded very pale orange (10YR 8/2) volcanic wackes and vitric tuffs and greenish gray (5G 6/1) lithic pebble wacke to pebble conglomerate lenses and beds. These rocks are all mineralogically immature, possessing a high percentage of unstable minerals and lithic fragments (see Appendix A for a detailed measured section of the lower "Rome beds").

The poorly indurated siltstones and mudstones characteristically weather to a light greenish gray (5GY 8/1) color. They exhibit a tendency to swell and fracture into tiny ramifying cracks on weathered surfaces. Bedding ranges in thickness from laminated (7/inch) to 3.5 inches. The siltstones have minor biotite flakes aligned along some bedding surfaces, with rare sub-angular to sub-rounded pebbles of black chert and quartzite also present within the beds. The silt-sized particles are composed of angular glass shards, quartz and plagioclase. The clay-size fraction appears cloudy, exhibiting a moderate yellow green (10GY 7/4) color in thin section (plane light). Minor calcite cement is present in both the siltstone and mudstone units.

The volcanic wackes and vitric tuffs weather to yellowish gray (5Y 7/2) or grayish orange pink (5YR 7/2). These rocks are better indurated than the siltstones and mudstones. Bedding thicknesses range from 2 to 27 inches. The wacke mineralogic assemblage is immature, consisting of angular glass shards, potassium feldspar, plagioclase, quartz and lithic fragments. The matrix ranges from 15-25% in the rocks examined. This matrix is composed primarily of zeolite minerals (after glass), and, in lesser quantities (5-10%) a moderate yellow green (10GY 7/4), moderately birefringent micaceous mineral with relief greater than balsam (celadonite?). The vitric tuffs are composed of glass shards that commonly have been altered completely to zeolites, leaving only ghost shard textures visible under the microscope. Two zeolites, erionite and clinoptilolite, were identified by X-ray from samples taken from the lower "Rome beds." Calcite cement is more abundant in the coarser clastic rocks than in the siltstones and mudstones; it occurs in quantities up to 20%. One calcite-cemented tuff possesses fresh shards exhibiting no zeolitization, possibly indicating that the calcite was earlier and prevented formation of zeolites. Calcite preceding zeolitization does not appear to be the general case however, for the zeolite crystals commonly have calcite at their outer margins, indicating zeolite formation predated calcite deposition.

The pebble wackes and conglomerates weather to a pale olive (10Y 6/2) and vary widely in their resistance to weathering, apparently in response to the amount of calcite cement. The pebbles are subrounded to rounded, polished, and are composed of volcanic fragments, quartzite, chert, polycrystalline quartz and very minor phyllite. Lithologic makeup of the pebble population varies considerably within the thesis area. The chert and quartzite fraction is largest in the northwestern area but in the southwestern area volcanic fragments predominate. Some of the volcanic pebbles exhibit extensive quartz veinlets (widths up to 0.30 mm) which cut through the groundmass and phenocrysts. The glass and plagioclase within the volcanic clasts exhibit extensive alteration to clay and zeolite minerals. The quartzite is made up of very fine grains that have highly sutured contacts. The polycrystalline quartz clasts are made up of from three to eight crystals, some possessing undulose extinction. The phyllite fragments are elongate and exhibit an internal parallel alignment of micaceous minerals.

The conglomerate matrix is similar in size and mineralogy to the volcanic wacke clasts previously described. Diagenetic alteration apparently has been more effective within the conglomerates, for celadonite (?), where developed, occurs as larger radial fibers and aggregates than in the wackes. Overall, zeolites dominate the matrix in terms of total percentage (up to 20%), but clay minerals do occur in minor amounts (5%). Calcite is present as a cement in amounts up to 25%. Where calcite exceeds 20% almost no matrix is present. In one calcite-cemented thin section part of the calcite is arranged in distinct crystals (0.05 mm) radiating outward from the margins of pebbles, and is surrounded by microcrystalline calcite cement. This recrystallization of the microcrystalline calcite into visible crystals may be in response to chemical changes between silica and calcite at the borders of the pebbles which resulted in the solution then reprecipitation of calcite.

Texturally the lower "Rome beds" are immature. Indicative of this immaturity is the high (15-25%) percentage of matrix, the poor sorting of all but the vitric tuffs, and the angular to sub-angular nature of the sand-sized particles. These factors indicate a low energy level during deposition. The pebbles are sub-rounded to rounded, but this is more a function of their size than of the energy at the depositional site. Packing density is generally poor, with approximately 20% porosity (estimation based on average number of contacts per grain, and the high percentage of relatively uncompacted silt- and clay-sized particles). Permeability is generally low due to the abundance of matrix. The vitric tuffs probably are more permeable than the other rock types since they are better sorted.

Sedimentary structures within the "Rome beds" include: scour-and-fill, tabular and trough cross-bedding (usage of Potter and Pettijohn, 1966, p. 71), intraclasts, normal and reverse graded beds, symmetrical and asymmetrical ripple marks, mud cracks, convolute bedding and concretions.

The scour-and-fill structures range from 0.5 inches to 18 feet in thickness with horizontal dimensions of up to 100 feet. These structures exhibit dominantly normal grading, but reverse grading occurs within the conglomerate lenses and beds (Figure 6). The small-scale scour-and-fill structures occur mainly within the wacke and siltstone beds and contain wackes to pebble wackes, but the larger structures cut through multiple beds and contain pebble conglomerates. The scours are indicative of unidirectional currents, while the dominant normal grading indicates decreasing transportation effectiveness during deposition.

Cross-bedding is well exhibited within the pebble conglomerates and, less frequently, within the wacke units. Trough cross-bedding is the more common type, occurring throughout the lower "Rome beds." Tabular cross-bedding (planar basal contact) occurs within some conglomerate beds. The maximum lateral extent of these tabular beds was not determined because of concealed contact relationships. One unit of a total thickness of four feet extends at least 1/2 mile in one direction and is a minimum of 200 feet wide.

Intraclasts, both angular and rounded (Figure 7), occur within the conglomerate channels. These intraclasts are composed of mudstone derived from the bottom or sides of the channel in which they are found and they have been transported very short distances.

Ripple marks occur within the volcanic wacke beds. Maximum amplitude recorded for current ripples was 0.20 inches with a wave length of 1.5 inches. Oscillation ripples (Figure 8) are of approximately the same order of magnitude. Convolute laminations were noted at several localities in the northwestern area. These convulate laminations may have been caused by sedimentary loading associated with a delta which was built up where a stream or streams entered the lacustrine environment.

Ovoid calcite concretions (3.5-12 inches in longest dimension) are abundant in some units within the lower "Rome beds." The concretions generally occur within coarser-grained sediments, but are present in mudstones. These concretions do not appear to be formed around a specific object, but rather, may have represented areas of higher pH than the enclosing rock during migration of $CaCo_3$-bearing fluids.

The basal contact of the lower "Rome beds" has been described (p. 20, 34). Laterally the "Rome beds" pinch out to the west, thicken to the east, and extend to the south probably 12-15 miles. To the north the "Rome beds" thin considerably, but the stratigraphic

Figure 7. Siltstone intraclast within a pebble conglomerate which has scoured-and-filled a cross-bedded wacke. Scale is 6 inches. Lower "Rome beds" along Owyhee River.

Figure 8. Oscillation ripple marks in lower "Rome beds." East of Owyhee River near Jordan Creek.

relationships were not examined more than four miles to the north of the area.

The lower "Rome beds" are overlain conformably by the upper "Rome beds," and disconformably by the Plio-Pleistocene sedimentary unit (QTs), the intracanyon basalt flows (QTba), and the uppermost fluvial-lacustrine unit (Qs). The "Rome beds"-QTba contact usually has three to four inches of relief developed upon the sediments with a baked zone of 2.5-6.5 inches thick often present. The overlying basalts (QTba) generally have a zone of vesiculation and/or contortion up to one foot thick directly above the sediments. The lower "Rome beds"-uppermost sedimentary unit (Qs) contact has a slight angular discordance, but of such a small degree it is evident only from a distance. On outcrop the contact may be picked on lithology and the higher degree of induration of the lower "Rome beds."

The source area problem for the lower "Rome beds" is somewhat more complex than that for other units in the area. From the lithologic descriptions it is apparent that sedimentary units not now exposed locally were providing detritus to the Rome basin. A volcanic sequence older than any now exposed in the area was also furnishing clastic material. Pebbles of these rocks have extensive quartz veins cutting through them. These, along with the chert, phyllite, and highly sutured quartzite indicate a deformed geosynclinal section section was a source area for Rome sedimentation. To determine which direction from the map area this source area lay, a current rose diagram (Figure 9) was constructed. This diagram, based on 73 cross-bed dip directions taken in fluvial channels cropping out in the northwestern map area, tentatively indicates a source area to the north or west. In the southwestern exposures of lower "Rome beds" the pebbles are dominantly from the andesite (Taf) and lower basalt flows (Tb). The primary sedimentary structures here definitely show currents from the west to southwest. On the western margin of the Rome basin, then, fluvial processes were providing clastic particles from an uplifted area tentatively established as being north or west of the map area. Fluvial processes were also bringing in material of local volcanic origin. These local volcanics in parts of the southwestern area were being provided by east- to northeast-flowing streams.

Although only fluvial transportation has been mentioned, it was not the only process involved in Rome sedimentation. Extensive tuffs of aeolian transport occur within the Rome stratigraphic section. Thicknesses of up to four feet of vitric tuff beds record volcanic eruptions. Since these beds are relatively thin and well-sorted, a source some distance away from the map area is postulated.

The depositional environment that existed during lower Rome sedimentation in the thesis area was dominantly fluvial-lacustrine.

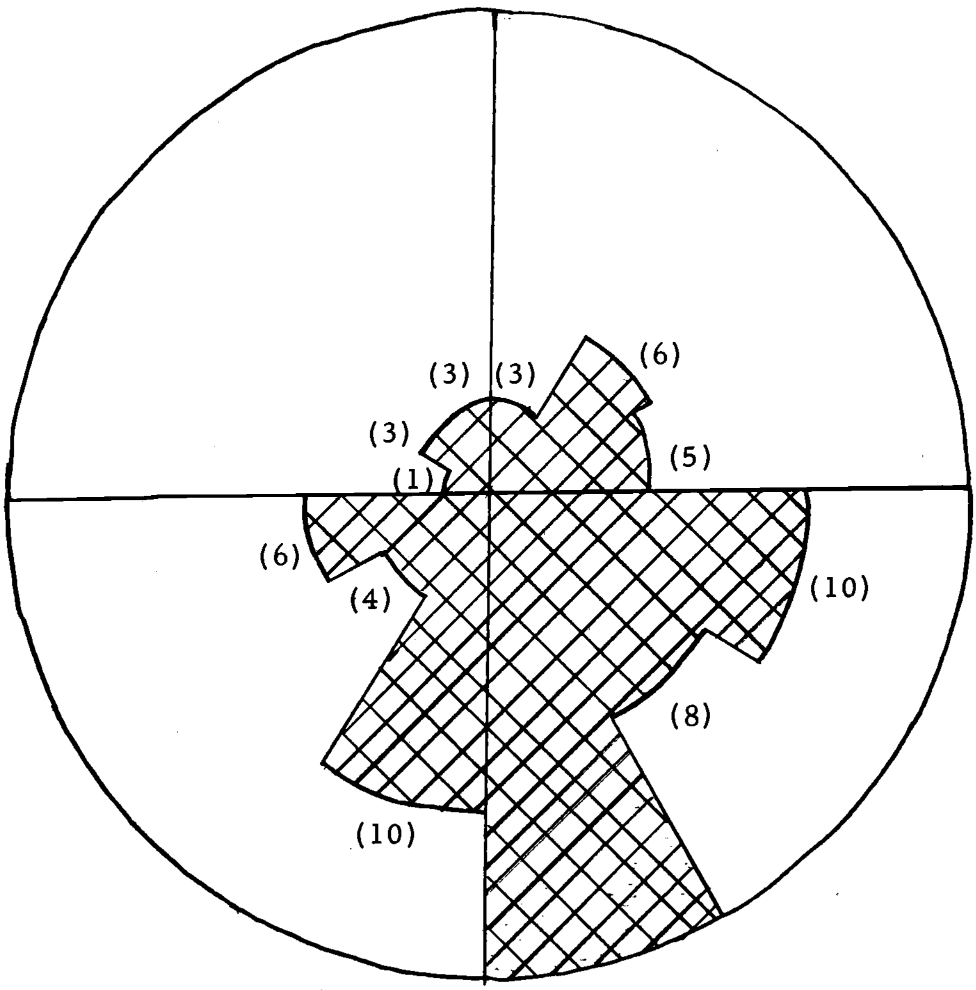

Figure 9. Current rose of 73 dip directions taken on cross-bedding within secs. 16, 17, 20-22, T. 31 S., R. 41 E. Measurements taken on the first, best defined bed encountered at the outcrop.

This is not similar to the lacustrine or the fluvial models postulated by Visher (1965), but rather, is similar to one of the environments discussed by Klein (1962, p. 1136). Klein described sedimentary structures and grain size associations similar to those encountered in much of the Rome sedimentary section. He interpreted the deposits as a periodically uncovered shallow lacustrine shelf or plain of coalescing deltas (alluvial fans possible in the Rome area), that was periodically reworked by wave action. Extensions of fluvial systems across this delta or plain produced primary structures normally associated with fluvial processes. The problem of whether individual conglomerate lenses or beds within the Rome sediments represented meander fluvial, reworked fluvial, or beach environments was not investigated thoroughly. It could be expected that fluvial bodies would be elongate parallel to transport direction and beach deposits would be elongate perpendicular to their internal structures (Potter and Pettijohn, 1963, p. 175-183). Several other criteria, such as conglomerate contact relationships, modal size analysis, and the specific geometry of the unit could serve to further distinguish beach from fluvial deposits; however, these factors were not dealt with in detail in this study.

In the western outcrop area (Plate 2) the abundant small-scale scour-and-fill and the subordinate thin pebble conglomerate lenses could indicate an environment of relatively extensive, gently sloping beaches, periodically subjected to erosion then deposition from small streams or sheet wash. These processes could periodically move previously deposited clastic grains back into a shrinking lake. This idea calls for a balance between subsidence, water level, and sediment input, with small changes in any one factor having considerable influence upon the environment.

Rainfall, a critical factor in the above considerations, has been estimated at 15 inches yearly (Shotwell, 1956, p. 20) during lower Rome sedimentation. Temperatures were very likely similar to those of the present day. The lake waters were probably saline and alkaline. Indicative of the alkaline nature of these waters is the apparent absence of a lacustrine biota and abundant alteration of glass shards to zeolites with no evidence for deep burial. Zeolitic formation is primarily a solution phenomenon and not a devitrification or hydration process (Deffeyes, 1959, p. 607); therefore high pH would favor solution of volcanic glass. Hay (1966) gives several examples of zeolites forming at very shallow depths (50-300 feet) in saline alkaline lakes characterized by dissolved sodium carbonate or sodium borate. However, the zeolites might represent intrastratal solution and thus may not be indicative of lacustrine conditions during deposition.

Deposition probably occurred in a shallow, saline fluctuating lake which had its shore line considerably modified by fluvial processes. The source area for these deposits probably lay to the north or west. Large amounts of material also were contributed as wind-deposited tuffs.

The age of the lower "Rome beds" is known to be Hemphillian. This age is based on vertebrate fossils that have been collected in the general area of Rome. Wilson (1937) listed moles, beavers, fish and otter fossil remains as being present in the Rome fauna.

Correlatives, in part at least, are the sedimentary member of the Grassy Mountain Formation of Kittleman et al. (1967), the Drewsey Formation of Shotwell (1963) and the Idaho Group of Malde and Powers (1962). Walker and Repenning (1966) correlate the Rome fauna with the Thousand Creek fauna of Merriam.

Upper "Rome beds". The upper "Rome beds" have a maximum thickness of approximately 100 feet (see Appendix B for measured section), and are present within the map area only in secs. 18-22, 28-33, T. 31 S., R. 41 E. (Plate 2). Because of erosion prior to the Pleistocene (?), thickness within these sections varies considerably. There is a general thickening of beds to the south.

The rocks are dominantly white (N 9) to pale yellowish brown (10YR 6/2) mudstone to yellowish gray (5Y 8/1) siltstone. Locally the mudstones grade into calcareous clays. Bed thickness ranges from 14 feet down to laminated (1/4 inch). The sediments are all mineralogically immature. One fairly extensive, 6-18 inch thick, silicified layer occurs within an extremely tuffaceous mudstone. This zone, which exhibits hackly to conchoidal fracture on outcrop, is composed of opalized glass shards. The silicified areas have irregular gradational (over 2-3 inches) boundaries with the host rock, for white (N 9) mudstone grades into a greenish gray (5GY 6/1) silicified area that has patches of, and is in lobate contact with, an opallized white (N 9) mottled, medium bluish gray (5B 5/1) central zone. Carozzi (1960, p. 140) describes silicified zones as a common feature of bentonites which have been altered subaerially.

The upper 14 feet of section is a vitric tuff which exhibits minor fluvial reworking of the upper six to eight inches. This unit has been extensively altered to the zeolite mordenite, and beds lower in the section contain erionite and clinoptilolite.

Texturally the upper "Rome beds" are immature. Large amounts of clay-sized materials are present and the minor wackes present are composed of dominantly angular grains.

Sedimentary structures include scour-and-fill, cross-bedding, calcite concretions, and 12-15 inch load casts (usage of Potter and Pettijohn, 1963, p. 145). These load casts (Figure 10) were developed at the base of the uppermost tuff bed by post-depositional injection of the underlying mudstone. This injection may have been triggered by a thixotropic change, or, more likely, by loading when

Figure 10. Load casts in upper "Rome beds." Just north of U.S. Highway 95 in sec. 33, T. 31 S., R. 41 E.

Figure 11. Cutout of upper "Rome beds" on left by Qs sediments. Thin silicified bed is just below white bed in left center of figure.

the intracanyon basalts (QTba) flowed over the sediments.

The base of the upper "Rome beds" is in conformable contact with the lower "Rome beds." However, laterally, up to 35 feet of upper Rome sediments were cut out prior to the deposition of the uppermost sedimentary unit (Qs), and angular elongate clasts of the uppermost tuff bed were incorporated within the Qs unit. On the east side of the outcrop area, the edge of this disconformity (Figure 11) trends northeast-southwest through the middle of secs. 21 and 28, T. 31 S., R. 41 E. From reconnaissance to the south it would appear the upper "Rome beds" thicken in this direction.

The upper "Rome beds" are distinguished from the lower "Rome beds" by the absence of lithic pebble conglomerates. This absence may have been caused by the burial or lowering of the lithic source area, by a change in direction or decrease in energy of the fluvial system providing the lithic clasts, or by the later erosion of the conglomerates after their deposition. Possibly more than one of the above factors played some part in controlling material delivered to the Rome area during upper Rome sedimentation.

Depositional conditions were similar to those in lower Rome time, that is, a saline alkaline lake or playa existed in a semiarid climate. Evidence of a major fluvial system is lacking; therefore, detritus probably was produced by local alluviation and wind deposition of tuffaceous material. With only local areas providing clasts it is not likely that a large enough drainage system would have been developed to maintain a permanent lake. This would favor the presence of a more playa-like environment subjected to intermittent flooding.

Age correlations are similar to the lower "Rome beds."

Pliocene - Pleistocene Units

Unnamed Sedimentary Rocks (Qts). Unnamed fluvial-lacustrine rocks crop out in secs. 13, 24, 26, 35, T. 31 S., R. 41 E., in a shallow, east-plunging syncline (Plate 2). Except where overlain by basalts, the sediments weather rapidly into rounded, featureless slopes. Excellent exposures of this poorly consolidated unit occur east of the thesis area where U.S. Highway 95 crosses the Owyhee River and climbs through the sedimentary unit (QTs) to continue eastward upon basalt flows (QTba).

Measured stratigraphic thickness within the map area exceeds 100 feet (see measured section, Appendix C). From outcrops exposed farther east in the vicinity of Arock, total unit thickness is estimated at 300-350 feet.

Lithologically, the rocks are semiconsolidated, light brownish gray (5YR 6/1) tuffaceous wackes and sands, yellowish gray (5Y 8/1) sandy siltstones, and minor white (N 9) mudstones. Bedding ranges from laminated (10/inch) to 30 inches. Pebbles similar to the Rome assemblage occur approximately 50 feet above the base of the unit. Rounded pebbles of indurated wacke from the "Rome beds" occur in lenses along with quartzite, chert and rhyolite approximately 75 feet above the base. The upper 20 feet of this sedimentary unit (QTs) is normally graded, starting with a pebble to cobble gravel similar to that contained in fluvial beds within the uppermost sedimentary unit (Qs), and grading into a sandy siltstone at the top.

A thin section of a tuffaceous wacke from this sedimentary unit (QTs) is dominated by glass shards (40%), and angular to subangular fine quartz and altered plagioclase grains (30%). A cloudy matrix of clay-sized particles, which exhibits local reorganization into clay (?) minerals, composes 25% of the thin section. The remaining 5% is composed of altered clinopyroxene grains. Mineralogically this rock is immature.

Texturally the sediments (QTs) are also immature. Poor sorting, abundant matrix and angular grains characterize the wackes. The pebbles and cobbles are better rounded and polished than the finer clasts; this is probably a function of size during transportation.

Structures are not as well exposed in these unnamed sediments (QTs) as in the underlying "Rome beds" (Tst). The QTs beds do exhibit normal graded bedding in several coarser-grained units; however scour-and-fill contacts between beds are also very common and trough cross-bedding is present.in the wackes and gravels.

The basal contact between the QTs sediments and the "Rome beds" has a slight angular discordance (Figure 12), with poorly indurated wackes overlying siltstones and mudstones. The unnamed sediments (QTs) are overlain disconformably by the intracanyon basalts (QTba) or the uppermost sedimentary unit (Qs). Only the basalt/sediment contact is well exposed, this exposure being in the cliffs just east of the Owyhee River near the mouth of Jordan Creek. Here the contact has three to four inches of relief with little baking of the sediments evident. To the southeast out of the area, basalts (QTba) fill an old erosional depression in the unnamed sediments (QTs) to a thickness of 75 feet.

Tuffaceous wackes are far more prevalent than mudstones in these sediments (QTs), a factor which distinguishes these rocks from the underlying "Rome beds" and the overlying uppermost sediments (Qs). The sources for these QTs sediments were varied. The Rome pebble assemblage and rounded pebbles of indurated wacke indicate the "Rome beds" provided material during part of QTs sedimentation. The angular quartz and plagioclase grains did not travel far, some possibly being of local origin. Angular tuffaceous debris was also being provided by aeolian transport. Uppermost QTs sedimentation was dominated by fluvial processes that provided pebbles and cobbles of grayish orange (10YR 7/4) quartzite and rhyolite.

Most of the QTs sediments were deposited in a fluvial

Figure 12. Contact between lower "Rome beds" and unnamed sedimentary rocks (QTs). Scarp is capped by basalts and overlying Qs sediments. Looking east up Jordan Creek.

environment. This is suggested by the dominance of sand-sized grains and the sedimentary structures typical of unidirectional transport. Deposition probably took place in a shallow depression which was more of a playa than a lake. At times the playa was inundated and mudstones were deposited. Semiarid climatic conditions still prevailed within the area. Five miles to the east the author collected the partially broken astragali of a camel (Dr. Arnold Shotwell, personal communication) from the QTs sediments.

This unnamed sedimentary rock correlates in part with the Idaho Group of Malde and Powers (1962). The Hemphillian "Rome beds" underlie these unnamed sediments (QTs), whereas the uppermost unnamed sedimentary (QTs) beds bear a similarity to units which contain Pleistocene vertebrate fossils. Therefore, the unit may span the Pliocene-Pleistocene boundary.

Intracanyon Basalt Flows (QTba). The intracanyon basalt flows crop out in secs. 1, 2, 4-7, 9-13, 18, 19 and 29-32, T. 31 S., R. 41 E.; in secs. 1, 12, 13, 24 and 25, T. 31 S., R. 40 E.; and in secs. 1, 10-12, T. 32 S., R. 40 E. (Plate 2). They characteristically form scarp-bordered benches or relatively flat to undulating flow surfaces overlain with an uppermost sedimentary unit (Qs) residuum. At least two of the lava outpourings were sufficiently separated in time to have ten feet of sediments deposited between them. Several partly dissected volcanic cones beyond the map area are thought to have been sources. One of these vents is Owyhee Butte, located approximately four miles northeast of the area. The other vent is Iron Mountain, located three miles to the northwest.

The thickness of the flows varies from 10 to 75 feet with the flow of greatest thickness exposed generally north and east of the Owyhee river. The westernmost flow is more extensive but considerably thinner, usually 10-15 feet. The eastern flow, which is generally restricted to south of Jordan Creek, is 8-12 feet thick except where filling depressions eroded in the underlying sediments.

These flows are light gray (N 7) to dark gray (N 4) to greenish black (5GY 2/1) vesicular basalts. Phenocrysts of olivine, displaying some iddingsite alteration, and minor augite are visible in hand specimens. Where deposited in water, the flows formed palagonite (?) breccias. On outcrop it is difficult to distinguish these basalts (QTba) from other basaltic units in the area.

Microscopically the intracanyon flows also are similar to the two older basalts. In the three thin sections of QTba examined the differences noted between the intracanyon basalts (QTba) and the lower basalt flows (Tb) are subtle: the intracanyon basalts seem to have a higher glass content and larger plagioclase crystals.

Diktytaxitic texture is exhibited by the intracanyon basalt flows. Vesicles are locally abundant enough to form a scoriaceous texture.

Structures vary from poorly developed columnar jointing to blocky to massive. Rarely the intracanyon flows are platy on outcrop.

Most of the basal contact of the intracanyon basalts has been described previously (p. 33, 44, 55), but the western intracanyon flow also interfingers with the basal uppermost sediments (Qs). At most outcrops the top of the intracanyon basalt is disconformably overlain by these uppermost sediments (Qs).

The sources for the intracanyon basalts and their mutual stratigraphic relationships are uncertain. It is felt that the eastern flow, which crops out east of the Owyhee River (undifferentiated from the northern flow stratigraphically above it on Plate 2), represents the initial outpouring of intracanyon lavas. The source area for this flow was to the southeast (?) out of the area. The western flow was probably the next lava flow laid down, with Iron Mountain as a possible source vent. The flow which crops out dominantly north and east of the Owyhee River would represent the last outpouring of basalt exposed in the area. The source for this flow is Owyhee Butte.

The intracanyon basalt flows correlate in part with the upper part of the Idaho Group of Malde and Powers (1962) and may also correlate with the lower basalt flows of the Cow Lakes region of Kittleman et al. (1967). A tentative age would be Pleistocene; however, these flows are quite close to the Pliocene-Pleistocene boundary and may be uppermost Pliocene in part.

Pleistocene Units

Upper Sediments (Qs). This unit crops out in secs. 1-13, 16-23, 26-35, T. 31 S., R. 41 E.; secs. 1-5, 8-14, T. 32 S., R. 40 E. and in secs. 1, 2, 11-14, 24, 25,T. 31 S., R. 40 E. (Plate 2). The uppermost sedimentary unit (Qs) has been lapped by the upper basalt flow (Qb) in most of the western map area, thereby limiting exposures to erosional scarps on the periphery of the flow. Topographic expression of the upper sediments elsewhere is characteristically as rounded, gentle to moderately inclined slopes, which exhibit deep (up to seven inches) "popcorn" surfaces; or as relatively flat areas covered by a desert pavement.

The maximum recorded thickness of this unit occurs along the southern boundary of T. 31 S., R. 41 E. Here almost 200 feet of a dominantly yellowish gray (5Y 7/2) laminated (12/inch), montmorillonitic (X-ray identification) mudstone crops out. This mudstone has fibrous diagenetic gypsum crystals along some bedding planes. Gravel lenses up to 300 feet wide and 8 feet thick make up approximately 10% of the Qs sediments. These lenses are scattered both horizontally and vertically throughout the entire Qs section, filling scoured channels within the mudstones. A gravel lens caps the measured section (see Appendix D). In the eastern outcrop area these gravels are made up of pebbles and cobbles of quartzite, rhyolite, andesite and chert. The light colored, fine- to medium-grained quartzite clasts are highly polished and contain quartz veins. The individual quartz grains exhibit moderate suturing along grain boundaries in thin section. In the western map area the upper sedimentary unit resembles the underlying lower "Rome beds" in that the larger size fraction is dominated by basalts and andesites of local origin. At rare exposures the gravels are well enough cemented by iron oxide to be considered conglomerates, but generally the cobble and pebble lenses and beds are unconsolidated.

The laminations within the mudstone often reflect changes in grain size, with alternating layers possessing more silt-sized particles than those layers above or below them. The gravels are poorly sorted, with the larger clasts being subrounded to rounded.

Structures present within the upper sediments include laminated bedding, scour-and-fill and cross-bedding. Both the scour-and-fill and cross-bedding are associated with the gravel and sand lenses and beds.

The basal contact has been described under previous units (p. 20 , 33 , 44 , 55). This unit generally is the uppermost stratum in the eastern map area, but in the west it is overlain by the upper basalt flow (Qb). Where exposed this sediment-basalt contact is fairly sharp, with little relief or baking developed on the underlying sediments, and little change in the texture of the basal basalt. The uppermost sediments may thicken to the south for a short distance out of the area, but extensive erosion has removed much of the unit farther south in the vicinity of Dry Creek.

These dominantly fine-grained sediments contain quartzite, rhyolite, basalt, andesite and minor black chert pebble and cobble gravels. The quartzites, which differ from those of the underlying "Rome beds" in their larger grain size, degree of grain suturing, and lighter colors, most likely originated from exposures in northern Nevada. It should be noted that the Owyhee River presently has, upstream from most of the upper sediment (Qs) outcrops, similar quartzites in its bed load. The fine-grained sediments are dominated by volcanic debris, some of which is of local origin--as probably are most of the andesite and basalt pebbles and cobbles. The minor chert most probably represents erosion of previously deposited Rome-type sediments; however, the chert may have been derived from the same source as the quartzite.

The depositional environment was more of a lacustrine "quiet water" type than was the underlying Rome environment. Poorly preserved ostracod (?) casts were found in one mudstone sample, indicating some organic activity in the aqueous environment. If the iron oxide in the conglomerate lenses is primary cement and representative of connate waters, then pH was somewhat lower than during Rome deposition. The fluvial channels contain much larger clasts than those of the "Rome beds," indicating greater fluvial velocities during their deposition. The Qs sediments may represent deposition at a local base level created by blocking of the Owyhee River by downstream volcanic activity. This damming may have been repeated several times resulting in the differing stratigraphic levels of the channels. It is felt that since the distinctive quartzite clasts do not extend beyond Dry Creek, these upper sedimentary rocks (Qs) do not represent deposits of the ancestral Snake River. Rather, they represent deposits of the Owyhee River which was probably much larger during the Pleistocene because of increased precipitation and glacial melt waters from highland areas.

The age of these sediments is given as Pleistocene by Walker and Repenning (1966). This age is based on vertebrate fossils collected from Qs sediments in T. 32 S., R. 41 E. A correlative in part is the Upper Snake River Group of Malde and Powers (1962).

Upper Basalt Flow (Qb). This unit crops out in secs. 1-3, 10-12, 13-15 and 19-36, T. 31 S., R. 40 E. and in secs. 1-4, 16-18, T. 32 S., R. 40 E. (Plate 2). Topographically the flow forms a nearly flat basalt surface between mountains to the west of the map area and erosional scarps on the south and east within the area. This basalt (Qb) laps Scotts Butte and the smaller cinder cone to the east. The upper surface of the flow is marked both by small depressions filled with silt and rare tumuli up to eight feet high.

Thickness of the upper basalt (Qb) varies from 8-12 feet. The rock is a dark gray (N 3) vesicular basalt with up to 3% olivine phenocrysts evident in hand specimen. This basalt weathers grayish brown (5YR 3/2) to medium gray (N 5) and characteristically exhibits a blocky weathering habit. Mineralogically the upper basalt is similar to those basalts previously described, with one exception -- the exception is the scarcity of iddingsite alteration of olivine.

Diktytaxitic texture is common in the upper basalt (Qb). Vesicles compose up to 20% of the flow and range up to 17 mm in diameter. Columnar jointing is not developed in the upper basalt.

A source for the upper basalt flow (Qb) most likely lay to the northwest of the area, for the flow extends for several miles in that direction. In the thesis area the basalts probably flowed over a very slightly dissected, subaerially exposed, lake bed.

This basalt (Qb), as well as the other basalt units in the area, is of the high-alumina type discussed by Waters (1962). Chemically these basalts are richer in Al_2O_3 and somewhat lower in Fe_2O_3 than the Columbia River tholeiite types. Waters (1962, p. 164) notes that the high-alumina basalts in the Pacific Northwest are associated with regions of block faulting and often are erupted from low lava cones or short fissures surmounted by cinder cones. He

(1962, p. 166) further suggests that these basalts were generated at depth, possibly in the mantle, then moved up faults to be extruded intermittently throughout the Pliocene and Pleistocene epochs.

The age of this flow is Pleistocene, correlating in part with the younger basaltic flows of Kittleman *et al.* (1967) and the Snake River Group of Malde and Powers (1962).

STRUCTURAL GEOLOGY

Regional Structure

Structurally the Owyhee Upland area is part of the Basin and Range structural province which is far better developed to the south and west. Pliocene-Pleistocene normal faults of large displacement, characteristic Basin and Range structures, are greatly subdued within the general map area; however, normal faults are common within the Miocene rocks. Apparently there was not well-developed in the thesis area the pronounced "horst and graben" topography characteristic of much of the Basin and Range region.

Thesis Area Structure

The structural pattern within the map area is relatively simple. It consists of gentle folds that have been intermittently active from the Miocene (?) into the Pleistocene, and faults that decreased in number and displacement from the Miocene into the Pleistocene (Plate 2, cross-sections).

Folding of the lowest stratigraphic unit (andesite flow rocks, Taf) is inferred to have occurred during the Miocene prior to outpouring of the rhyolite flow rock (Trf); however, this inference is based on observations made considerably east of the map area. By mid-Pliocene the folding associated with Rome deposition had begun, resulting in the depression of the rocks in the central and eastern thesis area. Stratigraphic evidence indicates that during latest Rome sedimentation the northern area, where rhyolite (Trf, Plate 2) is now exposed, began to rise. This is recorded by upper sediments (Qs) resting disconformably upon rhyolite (Trf). While this upward movement was continuing in the north-central map area, a gently east-plunging syncline was developing in the eastern map area (Figure 12). This syncline, in which the lacustrine-fluvial sedimentary unit (QTs) was deposited over "Rome beds," possibly represents the last negative movement in the area. In this syncline dips are generally on the order of 3-4°, making the synclinal axis difficult to locate.

Extensive normal faulting has affected the pre-Rome rock units in the adjacent townships. Southeast of the map area abundant northwest-trending faults have cut the lower basalt flows (Tb). Normal faults also cut the Tb unit within the map area. These faults lie along a northwest-trending system that is dotted by numerous volcanic cones, including Scotts Butte. Displacement of individual faults in this system is estimated to be at least 200 feet. Most recent movement along the system in the map area predated the upper basalt flow (Qb), which covers the fault zone with no evidence of displacement. Dip slip faults of small displacement cut the "Rome beds" (Figure 13). These faults have a random orientation, and the pronounced northwest pattern of the older faults is not developed. A monoclinal flexure is exposed in cliffs made up of "Rome beds" capped by intracanyon basalts (QTba) in sec. 10, T. 31 S., R. 41 E. This flexure, which very likely represents a fault at depth, affects the lowest intracanyon basalt flow, but not the youngest. Recent faulting is associated with the landslide deposits along Crooked Creek (Plate 2).

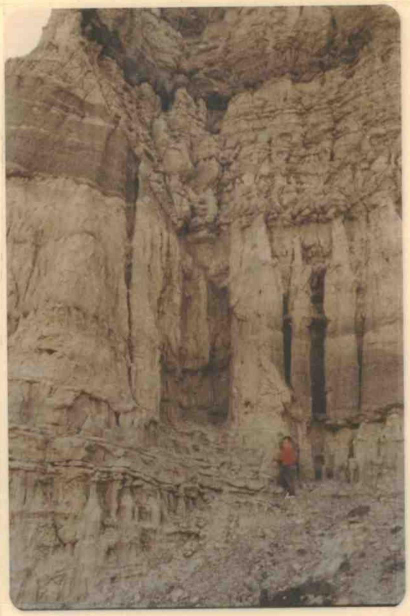

Figure 13. Normal fault in lower "Rome beds" looking east. Note "ribbed" weathering habit of some beds. Pebbles in the conglomerate lens have been drawn out along the fault surface. Along Owyhee River.

GEOMORPHOLOGY

The land forms in the map area are directly related to the stratigraphic units, but subordinate structural effects influence the topography in the west. Differential weathering and erosion has produced flattened benches or plains with canyons and dry washes bordered by cliffs that are held up by the more resistant units. The upper basalt flow (Qb), with a smooth surface broken by tumuli and pocked by small depressions, stretches to the north and west as a gently east-dipping plain. This plain is terminated in the western map area by a 15-55 foot scarp cut in the Qs sediments (Plate 2). Below this scarp is a poorly-defined irregular table land or bench developed in part on top of the intracanyon flows (QTba), and in part on the eroded lower basalts (Tb). This more irregular surface is caused by the varying elevations of the intracanyon flows, and by the incomplete stripping of the upper sediments (Qs). Erosion has left remnants of the upper sediments (Qs) as small rounded knobs or ridges rising 10-30 feet above a pebble-strewn surface.

Occurring at approximately the same elevation as the intracanyon flows a flat surface is developed upon the Qs sediments where they overlie the "Rome beds" in secs. 26-35, T. 31 S., R. 41 E. This surface also displays remnant knobs, ridges and pebble-cobble surfaces. The planing of these sediments may be related to a temporary base level established through damming by the intra-canyon basalts. The pebble desert pavement surface is the result of sheet wash and/or aeolian processes carrying away silt- and clay-sized grains. This old erosional surface is now being dissected by present day streams.

Faulting has controlled placement of the two dissected cinder cones that now form the topographic highs of the map area (Plate 2). Scotts Butte, the larger of the two, lies northwest of an east-dipping cuesta formed by normal faulting of the pumiceous wacke (Trs) and the lower basalt flows (Tb). The cuesta is highest (85 feet) just north of where it is crossed by U.S. Highway 95. It then decreases in height to the north, and disappears beneath the upper basalt flow (Qb). Faulting is also associated with the landslide deposits along Crooked Creek (Plate 2). Here the intracanyon basalts (QTba) and the underlying Rome sediments have slumped into hummocky slopes that border the creek for short distances.

The major streams within the map area are superposed from the upper sediments (Qs) into their present channels. Crooked Creek and the Owyhee River both exhibit meanders that have been deeply entrenched into volcanic flow rocks. The smaller intermittent streams are generally consequent, although the gullies cut into the western exposure of pumiceous volcanic wacke (Trs) along probable fault zones are subsequent. Crooked Creek, which is intermittent for several miles south of the area, rises from springs within its stream bed along the southern map boundary. This emergence may mark the eastern extent of the fault zone that trends northwest through Scotts Butte.

Terrace deposits, consisting mainly of gravels with sand lenses, occur along Crooked Creek and the Owyhee River (Plate 2). These terrace deposits are at least 15 feet thick with relatively flat upper surfaces. The gravels are generally dominated by clasts of volcanic origin; however, terrace deposits near Rome contain up to 30% quartzite debris. The terraces reflect lateral planation and alluviation as streams within the area responded to temporary changes in local base level. The base level changes may have been caused by recent volcanic activity farther downstream.

The upper basalt flow (Qb) surface has a discontinuous two-three inch, yellowish gray (5Y 8/1) mantle, composed of silt- and clay-sized particles. This sediment very likely represents loess derived from the presently exposed lacustrine beds within the general area. The silts and clays on the flow surface have been concentrated by sheet wash and intermittent stream activity into enclosed depressions, resulting in the formation of playas. These playas are small and shallow, being less than 1/4 square mile in area and containing less than four feet in depth of sediment. One playa has been developed in a depression upon the intracanyon basalts (QTba).

Here the sediments are obviously recycled, essentially being derived from the overlying upper sediments (Qs).

HISTORICAL GEOLOGY

Although only Cenozoic rocks crop out in the thesis area, the Paleozoic-Mesozoic history may be inferred from work done in Nevada by Roberts et al. (1958) and by observations on Oregon geology by Baldwin (1964). In eastern Nevada (east of 116° - 117°) rocks deposited in Middle Cambrian to Late Devonian time consisted mainly of carbonates and subordinate but areally extensive quartzites. In western Nevada shales, gray wackes, volcanics and cherts predominated. These two rock assemblages graded together in a poorly exposed transition section. The depositional strike of this geosynclinal basin apparently swung in a gentle arc to the northeast south of the Oregon-Nevada border, (Roberts et al., 1958). This would result in the Rome area during early Paleozoic time receiving either eugeosynclinal or transitional sediments. In Early Mississippian time uplift of the Antler orogenic belt signaled the first of several tectonic impulses which would greatly modify the geosyncline. This orogenic belt, located approximately in the transition zone between the eugeosyncline on the west and a miogeosyncline developing farther east, provided the source for large conglomerate lenses. These lenses, along with thrust blocks, moved out over the previously deposited sediments. Roberts et al. (1958) have documented further major orogenic movement along this same belt in the Pennsylvanian and Permian. They have also suggested Early Jurassic movements along the same trends. Baldwin (1964, p. 78) notes gaps in the stratigraphic record as recorded at the scattered Paleozoic-Mesozoic outcrops of eastern Oregon, indicating orogenic movement in the Pennsylvanian, Triassic and Cretaceous. Migration of the orogenic belt to a more western position may have taken place in the Triassic, while the Cretaceous orogeny probably signaled the beginning of the east-yielding, episodic Laramide orogenic cycle.

The Cenozoic history of the immediate region was dominated by continental volcanic activity, but nothing is known of the pre-Miocene history of the area. The oldest rocks exposed near the thesis area are middle Miocene clastic, basaltic and rhyolitic volcanics exposed north of Jordan Valley. These and later volcanics built up a constructional plateau which presently makes up the Owyhee Upland province.

The oldest rocks within the map area are andesite flows (Taf) which also covered extensive areas to the south and west. Some time after the andesite was extruded, the area was folded, and rhyolite flows (Trf) then covered (?) this folded surface in the eastern map area. Following the rhyolite flows, vitric tuffs were laid down over the area. These tuffs were reworked by fluvial processes and resulted in pumiceous volcanic wackes (Trs). In the eastern map area the wackes were removed from parts of the underlying rhyolite prior to extrusion of the lower basalt flows (Tb). However, before extrusion of the lower basalts (Tb), volcanic activity along a fault zone resulted in the building up of Scotts Butte and the cinder cone to its east. The scoria and flows (Tmv) of these cinder cones were reworked in some areas by fluvial processes into highly scoriaceous volcanic wackes (Tvs), the upper units of which may have interfingered with the lower basalts (Tb). The lower basalts were extruded to a considerable thickness in the southern map area, but they thinned considerably to the north where flows lapped or covered a highland of rhyolite (Trf). Faulting probably continued along with the development of the Rome depositional basin. This basin may very well have been structurally related to the Drewsey basin to the northwest. The fluvial-lacustrine "Rome beds" received pebbles of chert and quartzite possibly introduced from the north or west. Deposition continued at least into Blancan times, when the "Rome beds" became a source for sediments being deposited in a depression along the eastern map boundary. This sedimentary unit (QTs) continued to accumulate, possibly into the Pleistocene, then it was subjected to erosion. The eroded surface then was covered in part by intracanyon basalt flows (QTba). These flows very likely poured forth from vents associated with faulting outside of the map area. Between these intermittent flows, (and possibly related directly to them), began deposition of the upper sedimentary unit (Qs). These fluvial-lacustrine beds may represent damming by the intracanyon basalts of the ancestral Owyhee River as it flowed north from northern Nevada. Following deposition of these upper sediments, basalt from a vent to the northwest flowed over much of the western map area. The Owyhee River and its tributaries have continued to cut through the rocks of the area up to the present time, interrupted by only short episodes of aggradation. This aggradation has resulted in thin terrace deposits being laid down.

Climatically, the area was subjected to a continued drying trend from Miocene into Pleistocene times, a phenomenon related to uplife of the Cascade Mountains. The climatic changes associated with the development of glaciers in the adjoining mountains created many lakes in the Basin and Range province, but with final retreat of the glaciers semi-arid conditions returned to the area and have continued into the present.

ECONOMIC GEOLOGY

Zeolites

The economic value of zeolite minerals is related to their crystal structure. Zeolites are open-structured tectosilicates that have large channelways within the crystal lattices capable of adsorbing or exchanging ions and/or molecules without destroying the lattice. In the case of sodium-rich zeolites, this ion exchange property has been utilized in water softeners. It may also be possible to use clinoptilolite to adsorb radioactive waste from atomic reactors (Brown, 1962). Brown notes that clinoptilolite can fulfill three tasks when used as a filter for radioactive waste: (1) it can function as a means of economically and efficiently removing radiocesium from waste, (2) it can function as a solid medium to store radiocesium, and (3) it can function as a shipping medium to a storage or processing site. Of importance to geologists is the processing of the basic raw material. Clinoptilolite in outcrop concentrations above 80% requires only crushing to 10-50 mesh size, screening, and washing to become an excellent filter medium for radiocesium. Based on thin section examination, at least two of the vitric tuffs within the map area would exceed the 80% concentration requirement. Transportation costs and the total volume of clinoptilolite available are the major economic factors involved in mining the "Rome beds" profitably. Although much more abundant clinoptilolite is present in the John Day Formation of central Oregon, a block of claims has been staked in the Rome area. Assessment work on these claims has been maintained to date, so interest in the economic potential of these sediments continues.

Gravel and Building Stone

Gravel and building stone are two commodities of rather low economic value in the area. Gravel from a terrace deposit just north of Rome furnishes crushed rock for fill and asphalt base for the State Highway Department. Abundant gravel is available for local needs but the total economic value of the deposits is low. Blocks hand-sawed from the Rome sediments were used to build several early homes near Rome. In 1964 a quarry was opened near where U. S. Highway 95 crosses Crooked Creek to produce blocks of Rome sediment for sale in the Boise and Portland area. Because of rapid breakdown under weathering and the breakage during handling of the finished product, a suitable market did not materialize. The venture has now ceased operation and will probably remain closed.

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APPENDICES

Appendix A. Measured section lower "Rome beds", in dry wash bearing S. 03° E. from mouth of Crooked Creek and S. 87° W. from 1906 bridge across the Owyhee River. In center sec. 16, T. 31 S., R. 41 E. Traverse up northwest wall of the wash.

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disconformity: overlain by uppermost sediments (Qs); upper contact has 3"-4" scours.

Unit	Description	Thickness (feet) Unit	Total
19	Wacke: light gray (N 7), weathers to pinkish gray (5YR 8/1); tuffaceous, altered to zeolite; medium-grained; basal zone (2') contains 10% black chert pebbles; cross-bedded; upper 6' thin bedded (2"-6"); contact gradational; ledge-former	15.5	159.0
18	Siltstone: very light gray (N 8), weathers yellowish gray (5Y 8/1); poorly developed cross-beds; minor ovoid carbonate concretions up to 1/2" dia., contact gradational; slope-former	8.0	143.5
17	Wacke: light gray (N 7), weathers pinkish gray (5YR 8/1); medium-coarse-grained; angular quartz, glass shards, feldspar; cross-beds dip to east; carbonate cement; basal contact scour-and-fill (1/2" relief); ledge-former	2.5	135.5
16	Mudstone: very light gray (N 8), weathers yellowish gray (5Y 8/1); swells on exposed surfaces; laminated (less than 1/4"); minor pebble wacke lenses (1" by 18") in upper 10 feet; basal contact gradational; slope-former	16.1	133.0
15	Wacke: moderate greenish yellow (10Y 7/4), weathers very pale orange (19YR 8/2); coarse-grained; angular shards, possible vitric tuff; thin beds (1"-3") with carbonate cement; contact gradational; ledge-former	4.2	115.9
14	Pebble wacke: moderate greenish yellow (10Y 7/4) to greenish gray (5GY 6/1), weathers pale olive (10Y 6/2); coarse-grained; angular-subangular quartz, feldspar, shards (?), magnetite;; pebbles highly polished, rounded, quartzite, chert, volcanics; cross-beds dip S.W.; carbonate-cemented zone 6" thick near top; weathers into ribbed (2"-3") zones of varying resistance (Figure 13); contact gradational; ledge-former	5.5	111.7
13	Pebble conglomerate: greenish gray (5GY 6/1), weathers pale olive (19Y 6/2); pebbles (1/16"-1/2") form 60% of rock, composition as above; cross-beds dip 25° S. 50° E.; unit is lens-shaped, 100 feet wide; carbonate cement in lower 6"-8", ovoid to irregular carbonate concretions in upper 6'. Basal contact deep (10") scour-and-fill; ledge-former	7.6	106.2
12	Siltstone: very light gray (N 8), weathers yellowish gray (5Y 7/2); 3"-4" mudstone beds increase near top; laminated (less than 1/8") in mudstones; base has poorly developed corss-beds, dip 20° W.; forms steep slope; contact gradational	9.5	98.6

Appendix A. (continued)

Unit	Description	Thickness (feet) Unit	Total
11	Mudstone: light gray (N 7), weathers light greenish gray (5GY 8/1); minor fine-grained wacke beds (2"-4") near top; laminated (less than 1/8"); upper 6"-8" carbonate-cemented; swells on exposed surfaces; contact gradational; slope-former	9.3	89.1
10	Wacke: grayish yellow green (5GY 7/2), weathers grayish orange pink (5YR 7/2); grades from coarse-to-fine-grained near top; base contains 15% sub-rounded chert, quartzite, volcanic pebbles (1/16"-1/8"); cross-beds dip 12° S. 20° E.; bedding 10" to 15"; minor carbonate concretions; contact gradational; ledge-former	13.1	79.8
9	Silstone: very light gray (N 7), weathers yellowish gray (5Y 7/2); mudstone predominates in basal 3'; upper 1' has 25% ovoid (1"-3") carbonate concretions; bedding, 12"-21", weathers into "ribbed" zones; contact gradational; slope-former	10.5	66.7
8	Wacke: moderate greenish yellow (10Y 7/4), weathering to pale greenish yellow (10Y 8/2); medium-grained; angular quartz, glass shards, feldspar; bedded 2"-4"; cross-beds, 1/4"-1/8" thick; dip to S.W.; upper 2' well cemented by carbonate; 5% pebbles in basal part, contact gradational; ledge-former	5.0	56.2
7	Pebble Conglomerate: greenish gray (5GY 6/1), weathers pale olive (10Y 6/2); pebbles of chert, quartzite, volcanics: sub-rounded, polished; matrix coarse sand, poorly indurated; cross-beds dip S.; beds poorly defined; normal grade; basal contact scour-and-fill, 3" relief: slope-former	2.8	51.2
6	Siltstone: grayish yellow green (5GY 7/2), weathers pale greenish yellow (10Y 8/2); 15% pebbles (1/8"-1/4"); coarse wacke in basal 1.2'; beds 4"-9"; cross-beds dip N.; minor carbonate cement, ovoid to irregular (1/2"-2") concretions which weather moderate yellowish brown (10YR 5/4); contact gradational; slope-former	9.3	48.4
5	Wacke: very pale orange (10YR 8/2), weathers yellowish gray (5Y 7/2); coarse-grained, grades upward into fine-grained; upper 6" coarse-grained with 10% pebbles; beds 2"-8", subordinate mudstone (3") separations; lower 8" well cemented by carbonate; weathers into ribbed surfaces, contact gradational; ledge-former	11.9	39.1
4	Mudstone: grayish yellow green (5GY 7/2), weathers yellowish gray (5Y 8/1); swells on weathered surfaces; laminated (less than 1/8"); contact sharp; slope-former	4.1	27.2
3	Wacke: pale greenish yellow (10Y 8/2), weathers grayish yellow (5Y 8/4); medium-grained; current ripple marks on upper surface; beds 1/2"-2"; cross-beds have magnetite concentrations, dip 10° E.; carbonate cement in basal 10"; contact gradational; ledge-former	4.2	23.1

Appendix A. (continued)

Unit	Description	Thickness (feet) Unit	Total
2	Siltstone; pale greenish gray (10Y 8/2), weathers yellowish gray (5Y 8/1); fine-grained wacke in basal 4'; minor conglomerate lenses (6" by 38"); X-ray indicates erionite and clinoptilolite present; beds 6"-8"; contact gradational; slope-former	8.6	18.9
1	Wacke: grayish yellow green (5GY 7/2), weathers pale olive (10Y 6/2); angular, medium-grained quartz, feldspar, glass shards, biotite flakes; minor carbonate beds 4"-8", ovoid concretions (1"-2") in lower 5'; ledge-former	10.3	10.3
	Total thickness	159.0	

Base not exposed.

Appendix B. Measured section upper "Rome beds", taken up scarp bearing N. 25° W. from north end of U. S. Highway 95 bridge over Crooked Creek and N. 29° W. from south end of bridge. In N. W. 1/4 sec. 6, T 32 S., R 41 E.

disconformity: overlain by uppermost sediments (Qs); upper contact scour-and-fill; angular clasts of upper "Rome beds" incorporated in basal Qs unit.

Unit	Description	Thickness (feet) Unit	Total
6	Vitric tuff: bluish white (5B 9/1), weathers pinkish gray (5YR 8/1) to pale yellowish orange (10YR 8/6); angular glass shards much altered to mordenite; basal contact has 12" load casts of mudstone; no bedding; indurated; contact and undulating (1/8" relief); ledge former	14.0	100.0
5	Mudstone: grayish yellow green (5GY 7/2), weathers yellowish gray (5Y 7/2); upper 36" is highly calcareous (marl); glass shards, white anhedral zeoliteaggregates (1/16") in hand specimen; lamellar parting, laminated (less than 1/10"); contact gradational; slope-former	24.0	86.0
4	Silicified mudstone: bluish white (5B 9/1) grading into pale yellowish brown (10YR 6/2); conchoidal and hackly fracture; dominantly opal; forms resistant ledge; contact gradational	0.8	62.0
3	Silstone: yellowish gray (5Y 8/1), weathers to yellowish gray (5Y 8/1); upper 7' is muddy siltstone to mudstone; zeolites erionite and clinoptilolite; carbonate concretions (ovoid, 1" dia.); beds 2"-3" near base disappear upward; lens (3"-6") of coarse scour-and-fill sand near middle; poorly indurated; basal contact scour-and-fill, 1" relief; slope-former	28.0	61.2
2	Wacke: light greenish gray (5 GY 8/1), weathers yellowish gray (5Y 8/1): coarse-grained quartz, shards, feldspar; multiple scour-and-fill (1/4"-1/2" thick; mild carbonate reaction throughout; poor to moderate induration; beds 12"-7"; cross-beds dip to S.W.; scour-and-fill basal contact, relief 2"; moderate ledge former	3.2	33.2
1	Mudstone: yellowish gray (5Y 8/1), weathers grayish yellow (5Y 8/4); lower 4' siltstone to fine sandstone, upper laminated (less than 1/4"); swells on weathered surfaces, poorly indurated, forms slump slopes	30.0	30.0
	Total thickness	100.0	

Overlies lower "Rome beds"; contact with underlying olive gray (5Y 4/1) indurated wacke is sharp and undulating (1/2" relief).

Appendix C. Measured section, unnamed sedimentary rocks (QTs); measured up erosional scarp east of Owyhee River, bearing N. 10° W. from east end of U.S. Highway 95 bridge over Owyhee and S. 60° E. from old water wheel along Owyhee. In N.E. 1/4, sec. 24, T. 31 S., R. 41 E.

disconformity: overlain by intracanyon basalts (QTba); contact sharp, 1" baked zone in sediments; basalts are highly vesicular near base.

Unit	Description	Thickness (feet) Unit	Thickness (feet) Total
10	Sand: yellowish gray (5Y 7/2), weathers light gray (N 7) to very light gray (N 8) near top; medium to coarse-grained quartz, feldspar, magnetite, glass shards; upper 1" laminated (less than 1/10"!) mudstone; magnetite concentrated along cross-beds which dip 15° S.W.; minor 1/2" pebbles (rounded-sub-rounded) of quartzite and volcanics near bases; nonindurated to poorly indurated. Basal contact scour-and-fill (?); slope-former	18.5	110.0
9	Gravel: olive gray (5Y 4/1); rounded pebbles (1"-2" dia.) of quartzite, rhyolite, basalt; matrix coarse sand; (normally grades upward into 10" sand bed) minor cobbles (4" dia.) near base; nonindurated, basal contact scour-and-fill, 4" relief; sloper former	3.7	91.5
8	Sand: yellowish gray (5Y 4/1) to dark greenish gray (5GY 4/1), weathers to yellowish gray (5Y 7/2); medium- to coarse-grained; 10% sub-rounded pebbles in 2' zone at 84' in section; minor silt near top; nonindurated to poorly indurated; contact gradational; slope former	8.1	87.8
7	Gravel: olive gray (5Y 4/1), weathers to grayish yellow green (5GY 7/2); pebbles (1/4" to 1/2" dia.) rounded-subrounded, rhyolite, basalt, quartzite, chert, and indurated wacke ("Rome beds"); lower 10' poorly indurated; cross-beds dip 7°-10° N. Normally graded upward into unit 8; basal contact scour-and-fill; 2" relief; slope-former	2.4	79.7
6	Mudstone: pinkish gray (5YR 8/1) to white (N 9), weathers bluish white (5B 9/1); laminated (less than 1/8"); poorly indurated; "popcorn" weathering on surface; contact sharp and undulating (1/4" relief); slope-former	1.7	77.3
5	Wacke: light brownish gray (5YR 6/1), weathers to yellowish gray (5Y 8/1); coarse- to medium-grained sand; rounded pebbles of quartzite, rhyolite, basalt, wacke ("Rome beds") in lenses near base; heavy minerals in cross-beds which dip to S.E. near top; contact gradational; ledge-former	18.3	75.6
4	Siltstone: light olive brown (5Y 5/6), weathers to yellowish gray (5Y 8/1); planar bedding (1"-2") evident; moderate induration, minor carbonate cement; forms protruding (2"-3") ledges; contact gradational	2.4	57.3

Appendix C. (continued)

Unit	Description	Thickness (feet) Unit	Total
3	Sand: light brownish gray (5 YR 6/1), weathers to yellowish gray (5Y 8/1); medium- to coarse-grained quartz, glass shards; 5% pebbles (1/4" dia.), quartzite, volcanics, chert; nonindurated; basal contact undulating 1/2" to 1".	22.6	54.9
2	Siltstone: yellowish gray (5Y 8/1), weathers to same color; has beds up to 5" in which sand dominates; white, anhedral zeolite (?) aggregates scattered through lower nonindurated to very poorly indurated; contact gradational; slope former	21.8	32.3
1	Wacke: very light gray (N 8), weathers light brownish gray (5YR 6/1); quartz, feldspar, lithic fragments (basalt ?), minor pebbles (1/2" dia.) in basal 2'; nonindurated to poorly indurated; basal contact scour-and-fill, 2" relief; ledge-former	10.5	10.5
	Total thickness	110.0	

Angular unconformity (2°-3°) and overlies lower "Rome beds" with scour-and-fill contact.

Appendix D. Measured section, upper sediments (Qs). In north-trending dry wash 350 feet north of U.S. Highway 95, 3.7 miles east of Crooked Creek. N.W. 1/4, sec. 33, T. 31 S., R. 41 E. traverse S. 15° E. back across highway

Unit "skies out": upper contact erosional.

Unit	Description	Thickness (feet) Unit	Total
7	Pebble sand: light olive brown (5Y 5/6), weathers to same color; pebbles (1"-2" dia.) of quartzite, volcanics, 5% chert; concentrated in lenses (5"-6" thick, 15' wide); sand is coarse-grained; nonindurated; contact gradational; slope-former	6.0	199.0
6	Pebble wacke; yellowish gray (5Y 7/2), weathers reddish reflecting iron staining; moderate induration, cemented by iron oxide; pebbles similar to unit 7; contact gradational; ledge-former	3.2	193.0
5	Sand: dusky yellow (5Y 6/4), weathers grayish yellow (5Y 8/4); medium-grained, angular, quartz, feldspar, glass shards; multiple scour-and-fill (1/2"-1" thick); nonindurated; contact sharp and undulating (1" relief); slope-former	54.0	189.8
4	Mudstone: dusky yellow (5Y 6/4), weathers light gray (N 8); upper 10' abundant silt grains; fibrous gypsum along some bedding planes; laminated (less than 1/10") deep "popcorn" weathered surface (montmorillonite clays X-ray identification); poorly indurated; contact gradational slope-former	44.0	135.8
3	Silt: light olive gray (5Y 6/1), weathers light gray (N 8), 4"-6" clay beds (laminated, less than 1/10") in upper 25' nonindurated; contact gradational; slope-former	55.0	91.8
2	Mudstone: pale yellowish gray (10Y 8/2), weathers to yellowish gray (5Y 7/2); laminated (less than 1/10"); iron oxide staining along bedding planes; deep "popcorn" weathering; poorly indurated; contact gradational; slope-former	15.8	36.8
1	Silt; dusky yellow (5Y 6/4), weathers to same color; mostly covered, upper 4' exposed; basal contact scour-and-fill; forms gentle (2°-3°) slope in lower part	21.0	21.0
	Total thickness	199.0	

Basal contact with upper "Rome beds" sharp, scour-and-fill, 1/2"-1" relief.