

Figure 1. Map of the western Snake River Plain showing location of E-W seismic line, and features pertinent to ancient "Lake Idaho".

E-W seismic line and resistivity logs across the western Snake River Plain

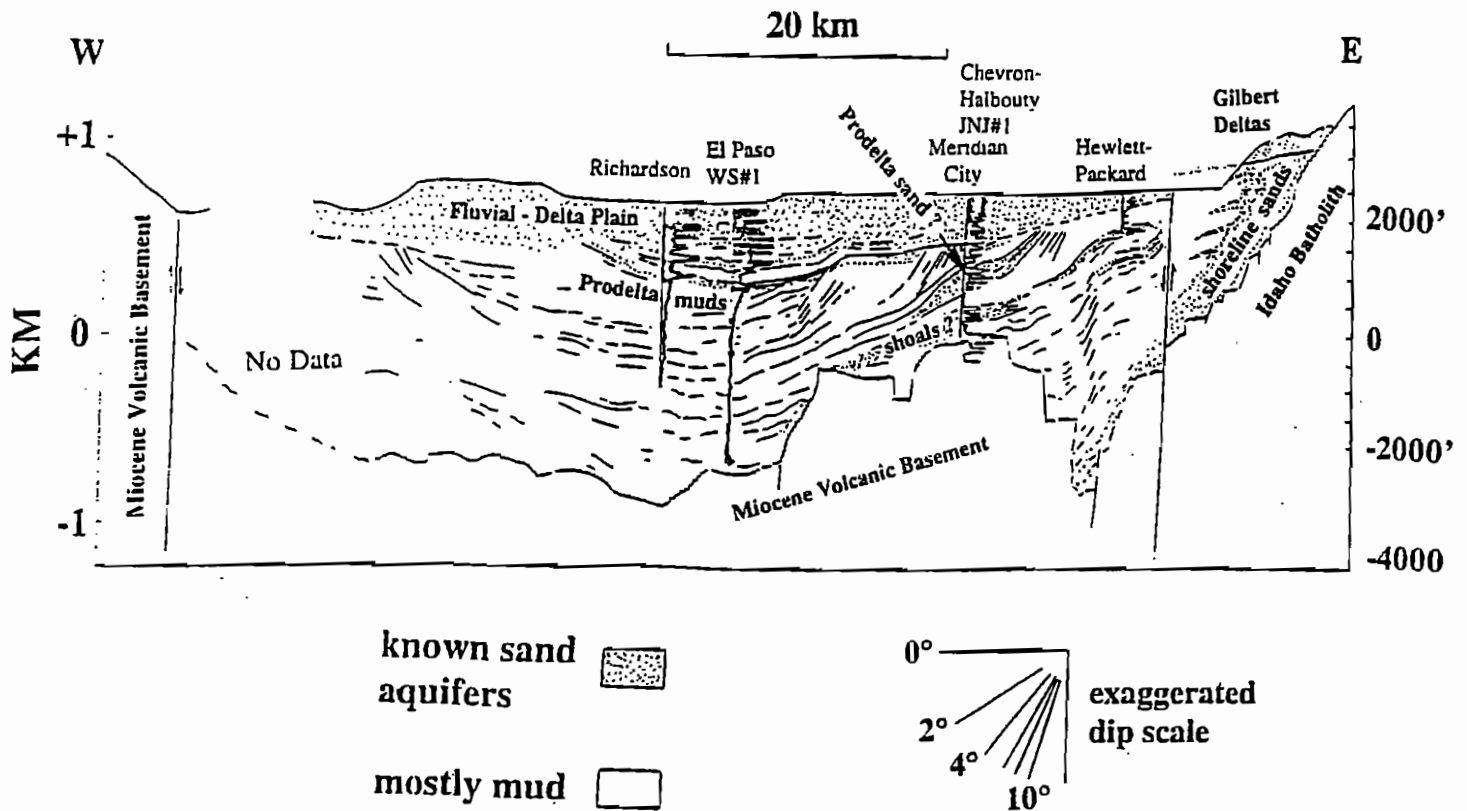


Figure 2. East - west cross section of the western Snake River plain showing configuration of strata interpreted from seismic reflections and location of sand aquifer systems identified by drilling and geophysical logs. Resistivity logs are shown for 4 wells. Excursions of the log trace to the right indicates sand aquifers, and low values to the left indicate clayey muds of low permeability. Vertical scale is greatly exaggerated, so that the inclination of the strata is incorrectly shown as being steep, whereas in reality the inclination from horizontal (dip) is everywhere less than 6 degrees.

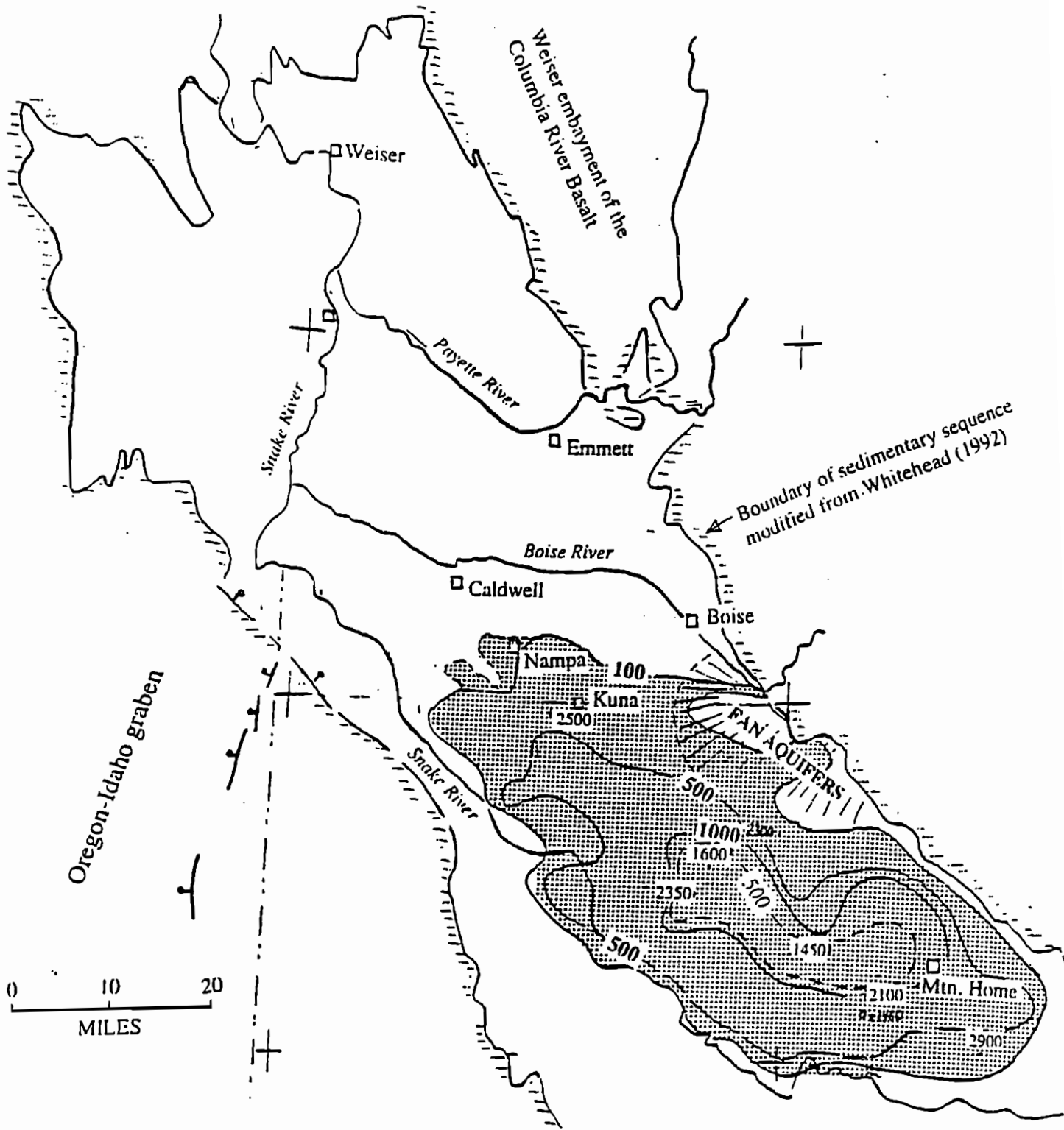


Figure 3. Map showing the Quaternary-aged basalt field of the western Snake River Plain. The basalt overlies part of the fan aquifers south of Boise. Thickness of basalt is shown by isopach contours in feet. Dashed contour shows area of over 500 feet of basalt below the water table. Spot elevations in feet are posted over the deeper parts of the basalt field. (after Whitehead, 1992)

hot groundwater. Several flowing and pumped artesian wells are capable of up to 1500 gallons/minute of 160°F water used to heat the State Capitol and office buildings, many commercial downtown buildings and several hundred of residences in northeast Boise. Conveniently an impermeable basalt and clayey sediment layer seals this deep geothermal aquifer from the overlying cold-water aquifer system (Wood and Burnham, 1987). At one time the city had hot and cold running water from artesian wells, although fluoride of 10 to 20 mg/l in the hot water renders it inadvisable to drink. For space heating, however, the geothermal system works very well for the city. As with all good aquifers, the Boise hot water system was on the verge of overdevelopment on account of declining pressures. It was declared a groundwater management area in the late 1980's curtailing further development

Geology of the overlying sedimentary section - the principal cold water system - is just now being worked out in a useful way for managing groundwater in the Boise area. Careful examination of drill cuttings and geophysical logging of water wells has been essential to this effort. Squires (1992) identified a buried alluvial fan system (Figure 3) in southeast Boise that grades westward into the river and lake sediment. Configuration of the sedimentary layers west and northwest of the fan is shown by tracing of seismic reflections on a section that extends east-west from Boise to Caldwell to Marsing (Figure 2). Sediments southeast of Boise are covered by young basalt flows and cannot be imaged by conventional geophysical methods. Earlier studies by Wood and Anderson (1981) and Wood (1994) indicated several river delta systems important to locating the important sand aquifers within a mostly mudstone sedimentary fill. This latest interpretation of geophysical data (Figure 2) shows the upper section of sand aquifers 1000 to 1500 feet thick that is broadly downward over the center of the plain. Configuration of strata

of this section contrasts with the strata below along a line regarded as an unconformity, or a sequence boundary. The upper sequence is thought to contain sediments of river flood plains, deltas, and smaller lakes - an environment formed as lake level slowly lowered as the Snake River began cutting an outlet through bedrock near Wieser into Hells Canyon, perhaps 2 to 3 million years ago. Lowering base level caused sand stored in deltas on the lake margin to prograde basinward. Down-faulting and down-warping by tectonic forces originally formed the deep lake basin, but as those forces diminished, the deep lake to filled with sediment and give way to river flood-plain systems.

Squires (1992) pointed out the importance of color change in sediments, the Boise fan aquifer being characteristically brown colors, and blue colors occurring more basinward in the section. Beukleman (1997) noticed a distinct color change in sediments described in water wells in the western part of the plain by Parma, whereby sediments above elevation 2200 ft ± 50 ft are described as brown colors, and those below are described as gray and blue-gray colors. This may be the approximate boundary where oxidized river sediments dominated the depositional system, and the gray sediments being those of the lake and delta. This upper sequence of sand and minor gravel aquifers and mudstone interbeds contains the color boundary. The upper sequence overlies thick mudstones of the deep lake environment of the central plain.

Well testing suggests that much of the upper sequence of aquifers is only semi-confined, and that some degree of interconnection exists in wells within the upper 800 feet, the major zone of pumpage. There is no evidence for a widespread blanket of blue clay as earlier reports have indicated, nor is such layer expected to be deposited in a predominantly river and lake delta environment.

The lower thick mudstone sequences formed as delta systems prograded into a deep lake environment, delivering their suspended load of silt and clay to the prodelta slopes and the deep lake by falling from suspension, and by density flows along the bottom. In this lower section good sand aquifers do occur within about 20 miles of the northeast margin of the plain. One concept of sand distribution in the deep section under consideration is that high runoff from the mountainous region north of the plain gave rise to river systems that issued into the lake from the northeast margin - analogous to the Boise and Payette Rivers today. These produced sandy beach, shoal, delta, and prodelta environments. In contrast, good aquifers in the deep section seem to be lacking in the central and south part of the plain. Runoff is low from the south side of the plain, (Owyhee uplands): only the small Bruneau River presently delivers significant runoff and sand sediment. It is speculated that the main river system feeding the lake, the Snake River, flowing into the great lake from the southeast, slowly prograded its delta system northwestward during the time of the deposition lower section. Most of the sand from the Snake River accumulated at the floodplain and active delta way off to the southeast, while the center of the basin was still a deep lake.

The oldest, and very deepest sediment laying next to the volcanic rock has not been studied in much detail. These early sediments of the basin are mapped as the Chalk Hills Formation on the south side of the plain. The formation is composed of both river and lake sediments and contains abundant white volcanic ash layers (Middleton and others, 1985) dated between 5 and 8.4 million years (Kimmel, 1982). Exact correlative strata on the north side of the plain have not been identified.

Sedimentation in the western Snake River Plain is in many respects similar to the model presented by Lambiase (1990), where the dominant structure is a rapidly forming half graben filled initially by river

deposits, overlain by thick deposits of a deep lake overlain by delta deposits and a final river-deposit phase as the basin fills and drains. Much of the relief of the western plain probably occurred by faulting between 12 and 9 million years ago, shortly after the major period of rhyolite volcanism in this area. The work of Clemens (1992) identified the main period of faulting; however, I believe his estimate of 14.5 to 9 million years to be too old, because rhyolite volcanism was active here from 14 to 10 million years. During the initial phases of volcanism, this area was probably a volcanic upland analogous to the Yellowstone area described by Pierce and Morgan (1992). The greatest amount of faulting and vertical shift of the volcanic surface appears to be on the southwest margin against the Owyhee Mountains, but the basement configuration shown in Figure 2 is not a simple half graben.

Faults vertically shift the sedimentary section and aquifers, but most of the faulting in the sediments on the northeast margin of the plain is less than a few hundred feet. One important fault has been precisely located beneath the city by a seismic survey in 1996 by Liberty (1996). It is part of a system identified by Wood and Anderson (1981), and Squires (1992) called the west Boise-Eagle fault. These studies recognize a shift in the geologic section of about 800 feet with the upthrown section of older mudstones lacking major aquifers beneath downtown and NW Boise, generally north of the Boise River. Offset along this fault explains how sediments in the Boise foothills might match those beneath the city. The base of the coarse-sand "Gilbert-type" deltas in the foothills probably matches delta sediments such as those found in the Hewlett-Packard well of east Boise (Figure 2).

Dip of sand units is generally less than 6°, some of which is depositional dip, with a superposed dip due to down-warping of the basin (Figure 2). However, one must take into account the dip of strata in trying to

correlate sand aquifers in the basin, because even a dip of 4°, will produce an elevation difference of 370 feet per mile. One should view with distrust, cross sections attempting to correlate over distances of several miles, unless the section is along strike, and the sedimentary facies is identified.

I have been interested in relating the upper depositional sequence (labeled "fluvial and delta plain on Figure 2) to the lowering and draining of Pliocene "Lake Idaho". A mechanism for the lowering of "Lake Idaho" was laid out in a clever analysis of landforms by Harry Wheeler of the University of Washington and Earl Cook at the University of Idaho in 1954. They showed that the lake must have overtopped its spill point at a drainage divide of the Columbia-Salmon Rivers system and the Lake Idaho drainage area - which they thought was at the Oxbow of the Snake River (Wheeler and Cook, 1954). The spill point may have been about 50 miles upstream from the Oxbow at a bedrock ridge near Wieser. Dead Indian Ridge has a steep V-shaped incision by the present Snake River at Cobb Rapids (Wood, 1994). The river must have cut down through basalt bedrock at the ridge, and also lowered the grade of ancestral Hells Canyon. I believe that upper depositional sequence in the plain relates to this downcutting and I have wondered how long it may have taken to incise the ridge some 700 feet to the present river bed as indicated by the present landforms. Did it occur quickly? Probably not, inasmuch as the spill point is basalt bedrock, and the canyon is hard Paleozoic and Mesozoic rock. Schumm and Ethridge (1994) have summarized known rates of valley incision into bedrock by major rivers, and the range is 9 to 30 cm per 1000 years, and an average of about 15 cm/1000 years is reasonable. At the latter rate, cutting 215 meters (700 feet) might have required 4.7 million years, and at the fastest rate perhaps 2.3 million years. Thus it is reasonable that the upper sequence of prograding deltas and river flood plains could have formed in

response to slow base level lowering within the last 5 to 2 million years - which is indeed, about the age estimated for the upper Glens Ferry Formation.

The last chapter in the geologic framework of the Boise Valley was the emptying of the lake, and incision of lake deposits by the Boise River, laying a 40 to 60 foot thick veneer of gravelly braided stream deposits across the floodplain. The river did not lower its bed continuously, but rather did so episodically, or in steps -- probably related to major shifts in climate during the Pleistocene Ice Ages. Evidence for this kind of downcutting is in the 8 terrace levels distributed irregularly in elevation up to 450 feet above the present river level. The widening of the braided flood plain and the veneering of gravel is thought to be associated with times of mountain glaciation in the headwaters of the Boise River (Othberg, 1994). Glaciation flushed outwash gravels into the streams producing a greater load than could be carried away from valley at the foot of the confined mountainous reach. This caused aggradation of gravel deposits and valley widening. As glaciers melted and waned to an interglacial time, the main stream, relatively sediment poor, entrenched the gravel deposit, and graded to a still lower base level of the downcutting Snake River. Over the past 2 million years there have been many glacial and interglacial periods to account for the many terraces. In the interval 1.5 million to about 100,000 years ago, basalt eruptions occurred on the plain to the south and also in the upper Boise River basin. These lava flows covered some terraces, and much of the plain east and south of Boise with young basalt (Figure 3), some of which contain modest groundwater resources but with very limited recharge, for only small intermittent streams flow across them..

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