THE GEOLOGIC HISTORY OF MOSCOW AND A MODEL FOR MOSCOWS` GROUND WATER RECHARGE-A NON-REFERENCED GENERALIZED DISCUSSION

by John Bush, 1996

INTRODUCTION

A geological model of the subsurface conditions of Moscow, Idaho was constructed by integrating surface and subsurface data with knowledge of regional geologic history. The general lack of outcrops in the Moscow area, also necessitated utilization of geologic mapping in surrounding areas to construct that model. A ground water recharge model for Moscow is proposed based on the geologic history of the area and on assumptions about the subsurface.

Moscow is located on the eastern edge of the Columbia Plateau where Miocene basalt flows (17ma to 6ma) overlie Precambrian and Cretaceous basement rocks (Fig. 1). Interbedded with and overlying the basalts are sediments that were deposited in response to the encroaching flows. These sediments and basalts occupy a paleo drainage developed on basement rocks, which rim and project above the area in a semi-circular, crescent shaped pattern surrounding Moscow on the east, north and south. The pre-basalt drainage was west to northwestward, and the infilling basalts therefore thicken in that direction. The present day drainage patterns along with the distribution of basalt and associated sediments define what is called the Moscow-Pullman basin. Moscow occupies the eastern end of this basin and obtains its water supply from aquifers in the basalts and sediments . The question of "How do these aquifers get recharged?" is important to the city of Moscow and nearby Pullman, Washington.

Basement rocks consist of Precambrian and Cretaceous units. Precambrian units of quartzite, siltite, and argillite, were intruded by granitoid magma in the Late Cretaceous (approx. 65ma). Most of the Precambrian rocks were metamorphosed into gneiss and schist. In places, there are mixed units of both Precambrian and Cretaceous rocks. Subsequent uplift and erosion during and after magma emplacement caused development of a youthful, west to northwestward flowing drainage system. In areas surrounding Moscow weathering and structural features in both the Precambrian and Cretaceous units control groundwater storage on a local basis. Overall these rocks do not provide aquifers with large yields and movement of any significant amounts of water through these units is not likely. Thus, it is believed that the basement rocks provide a barrier around most of the basin to regional ground water movement to and from the north, east and south.

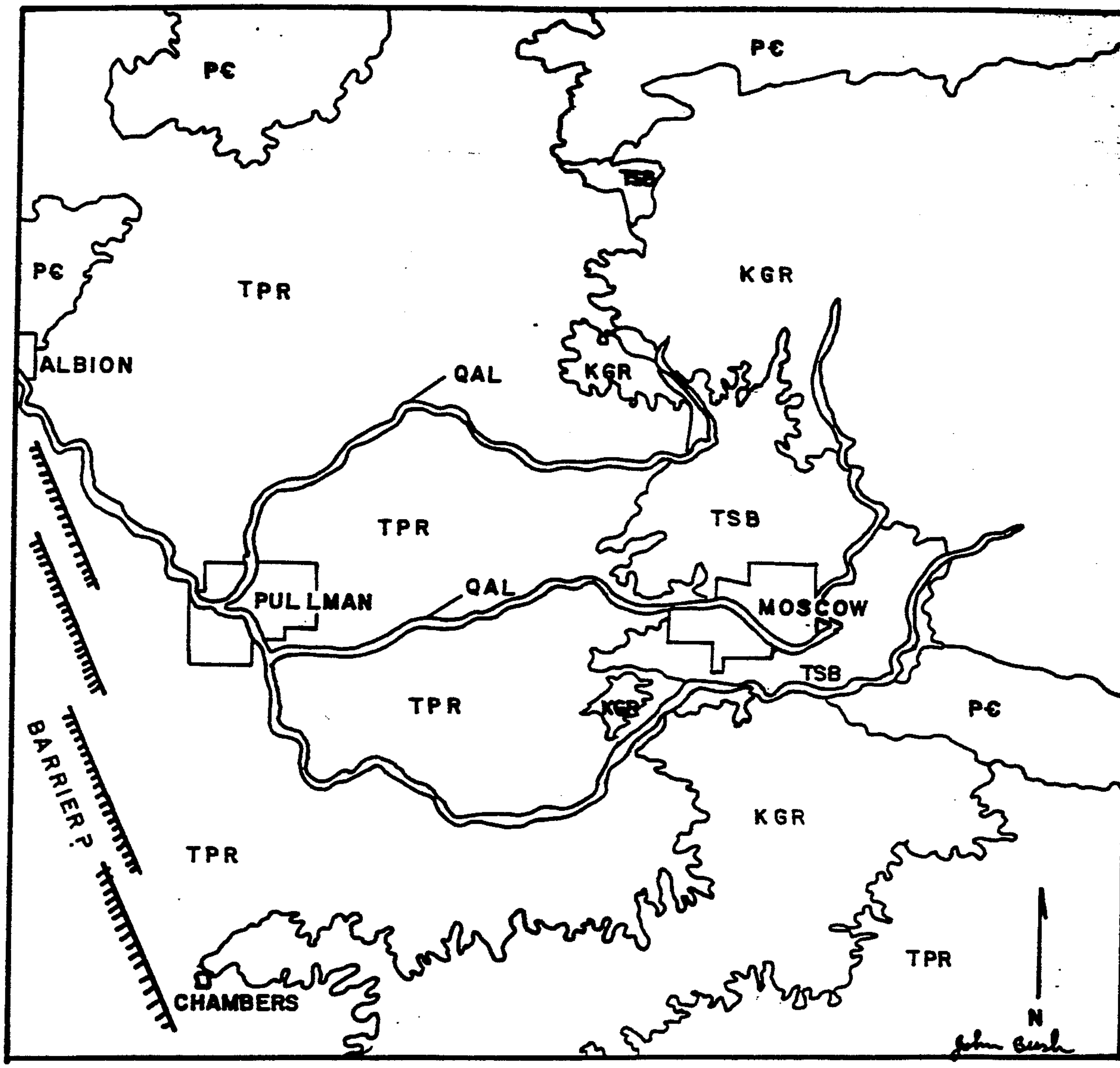

Figure One-- Generalized geologic map of the Moscow-Pullman area. P€=Precambrian, KGR=Cretaceous granitoid, TPR= Priest Rapids Basalt, TSB= Sediments of Bovill, QAL= Holocene Alluvium.

BASALT EMPLACEMENT

At approximately 17 ma the first of the basalt flows, which belong to the Columbia River Basalt Group, were emplaced into the basin from the west. Early flows did not cover the entire basin, but they disrupted erosional patterns and caused deposition of clastic sediments in the eastern end of the basin beneath what is now Moscow. Sediments that are associated with the Columbia River Basalt Group on the eastern end of the Plateau belong to the Latah Formation. Locally the sediments have informal and formal member names depending on distribution and stratigraphic position. Figure Two illustrates proposed nomenclature for Miocene units of the Moscow area. Similar to the earliest flows, basalts of the Grande Ronde Formation (17ma) also entered the basin from the west, most of which did not reach Moscow, while others extended as far as the present day eastern city limits. These flows are part of the same units that cover much of the present day Columbia Plateau and comprise over 80% of the volume of the Columbia River Basalt Group. In Moscow, these flows caused rapid sedimentation in environments that ranged from low energy lakes to high energy fluvial environments. Figure Three illustrates one possible paleo setting during the deposition of these sediments. Although the precise distribution of individual environments is not known, coarse deposition dominated near basement highs and fine deposition dominated to the west. The older sedimentary units, informally called the sediments of Moscow, are interbedded with the Grande Ronde and belong to the Latah Formation. Grande Ronde flows along with the sediments of Moscow form what is presently called the deep or Grande Ronde aquifer. Westward the sediments of Moscow thin rapidly towards the Washington-Idaho boundary and the Grande Ronde aquifer in Pullman consists primarily of basalt units.

At approximately 15ma, the entire Plateau including Moscow, was covered by a group of flows belonging to the Priest Rapids Member(Tpr, Fig. 1) of the Wanapum Formation. In Moscow, this flow or flows went over a thick sediment sequence (Vantage Member of Latah Formation) that now separates the Priest Rapids from the earlier Grande Ronde flows and sediments of Moscow. Along the very eastern end of the basin the Priest Rapids flowed onto basement rock highs, but in places there is vertical continuity between early and late sediments. Emplacement of the Priest Rapids flows again caused deposition of sediments from nearby weathered basement rocks. These sediments, referred to as the sediments of Bovill, form a westward thinning wedge over much of Moscow between the loess and the underlying basalt flow or flows,and in places lie directly on weathered crystalline rocks(Tsb, Fig.1).

The Vantage Member is a clay-rich interbed over much of Moscow, which acts in places, as an aquitard and causes separation of the lower Grande Ronde and upper Wanapum aquifers over a part of the Moscow-Pullman basin. On the every eastern edge of the basin, it is coarser and vertical connection in places from the surface to the Vantage and on down to the lower units of the sediments of Moscow is likely. Westward towards Pullman the Vantage interbed thins to a few feet in thickness and more exchange between the two aquifers is expected. Figure nine illustrates the overall pattern of expected ground water movement in the eastern portion of the Moscow-Pullman basin.

The recharge model illustrated is consistent with the geologic understanding of the Moscow-Pullman basin and is believed by the author to be the primary one that has operated since the emplacement of the Priest Rapids Member. However, other possibilities and potential modifications need to be mentioned and briefly discussed.

There is the possibly that our aquifers may be fed from the west or from breaks in the surface trend of basement rocks on the north and northwest end of the basin. Data is lacking on the subsurface between the "breaks" in the basement rocks that rim the northern and northwestern part of the basin. Those areas could be filled deep paleo-channels. No model of the Moscow-Pullman basin, geologic or hydrologic, can be fairly tested without understanding more about the subsurface in those areas.

Percolation of water from rainfall through the loess over the entire basin into the upper aquifer system and then down into the lower aquifer system has been researched. Consideration of the physical properties of the loess coupled with field observations during heavy runoffs places considerable doubt that this method is significant. In addition, quantitative data also points to the same conclusion.

There is the possibly that our aquifers are recharging right at the crystalline-basalt contact. No stream has been documented to be losing its discharge across the contact although there is geomorphic evidence that many small streams suddenly change to a lower gradient at the contact area and begin sedimentation. This method of recharge would operate in conjunction with the distribution of coarse-grained units the Latah sediments.

The subsurface configuration of the pre-basalt surface throughout the basin and in Moscow is not well defined. There is the possibly of deep, narrow, pre-basalt canyons that could be responsible for channeling subsurface movement of ground water. The existence of such channels beneath eastern Moscow would be consistent with the geologic history of the area. It should be noted that such channels would not necessarily receive recharge directly from the surface but would be fed by the irregular, and interconnecting network of coarse-grained units within the Latah Formation.

SEDIMENTS OF BOVILL

Deposition of the sediments of Bovill would have been relatively rapid, and sharp contacts with the scoriaceous flow tops and rubbly, highly fractured flow fronts of the Priest Rapids Member are likely. Along the basement-basalt contact sediments consist of poorly sorted, conglomeratic, micaceous sands interbedded with kaolinite-rich clays. Over the western end of Moscow these sediments are dominated by clays with minor interbedded lenses, and locally laterally continous units of sands and silts. Figure Four is an isopach map illustrating present distribution of the sediments of Bovill in Moscow. Figure Five is a gravel-sand to clay ratio (percentage) map illustrating distribution of coarse material in the same sequence. Similar to earlier paleo-settings depositional environments ranged from fluvial dominated areas near margins to lake and flood plains on the west. Discharge channels developed at times extending across the depo-basin from east to west. Figure six is a conceptial illustration showing potential depositional setting for part of the sediments of Bovill.

Similar to earlier sedimentation, deposition of the sediments of Bovill was interrupted by renewed vulcanism, but these basalt flows did not come from the west as before. Instead they were intravalley flows of local extent. These local flows and the arrangement of coarse-grained units within the sediments of Bovill are considered to play an integral part in the movement of shallow ground water in the eastern part of the Moscow-Pullman basin. There is considerable documentation that the coarse-grained units become saturated, and where in contact with flow fronts and flow tops ground water connections between the basalts and sediments is likely.

TECTONIC BACKGROUND

The tectonic history of the region during and after basalt emplacement is important to understanding constraints on a subsurface model of the Moscow-Pullman basin. Tectonic activity in the Moscow-Pullman basin has been minimal since Priest Rapids flows covered most of the basin. However, considerable pre and post Priest Rapids subsidence beneath Lewiston and the Tri-cites areas of the Plateau affected distribution of numerous basalt flows. This subsidence created boundaries that separate the Moscow-Pullman basin from those regions geologically even though they are all underlain by similar basalt units. Most importantly is the existence of a geologic boundary at the west end of the basin extending from southwest of Chambers northwestward towards Albion(Fig. 1). There are several changes that occur between east and west across this "zone" or "lineament". The evidence for a geologic boundary in that area is so compelling that the likely hood of a subsurface hydrological barrier at that locality

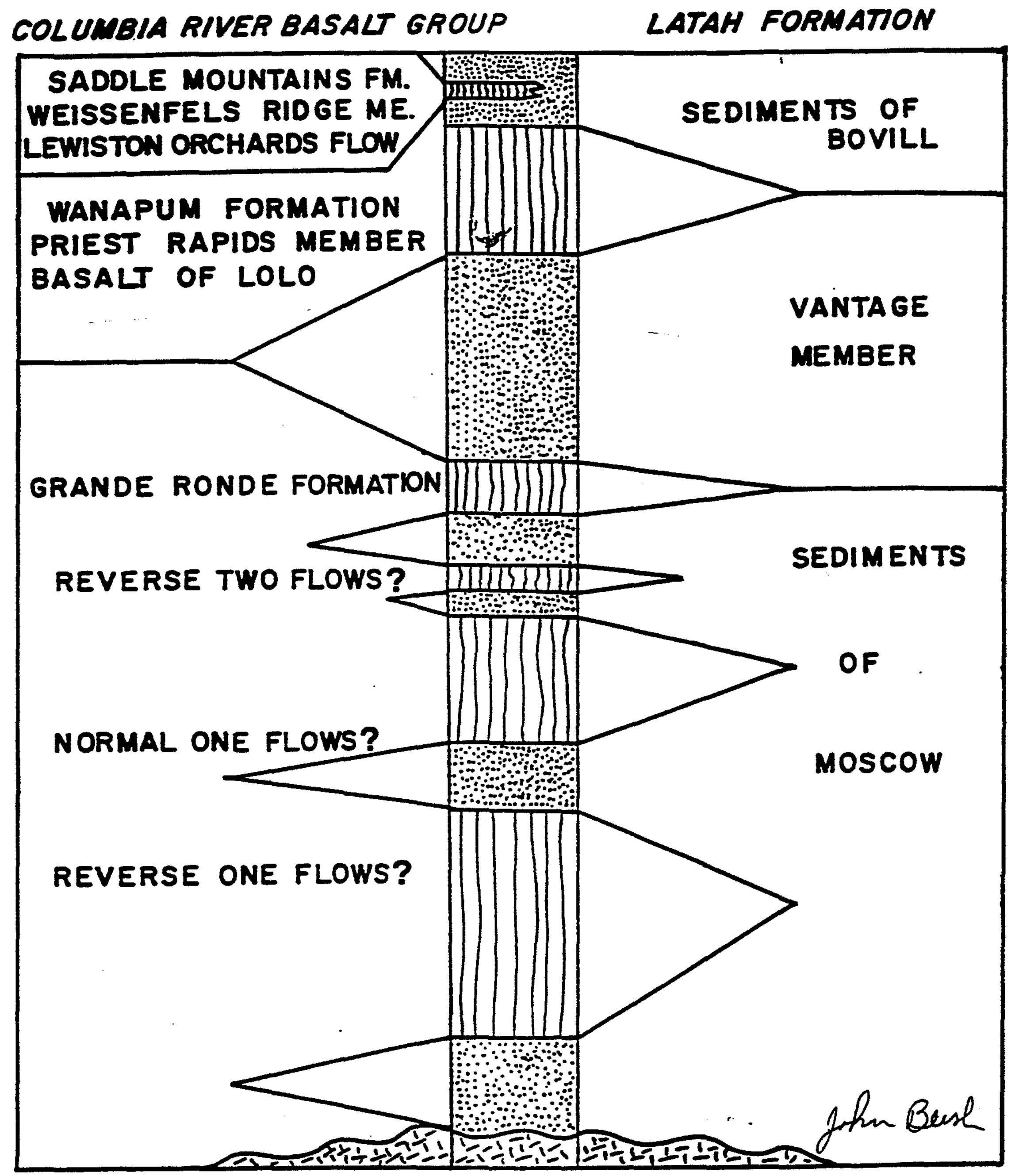

Figure Two-Miocene stratigraphic nomenclature for Moscow Basin, Latah County, Idaho.

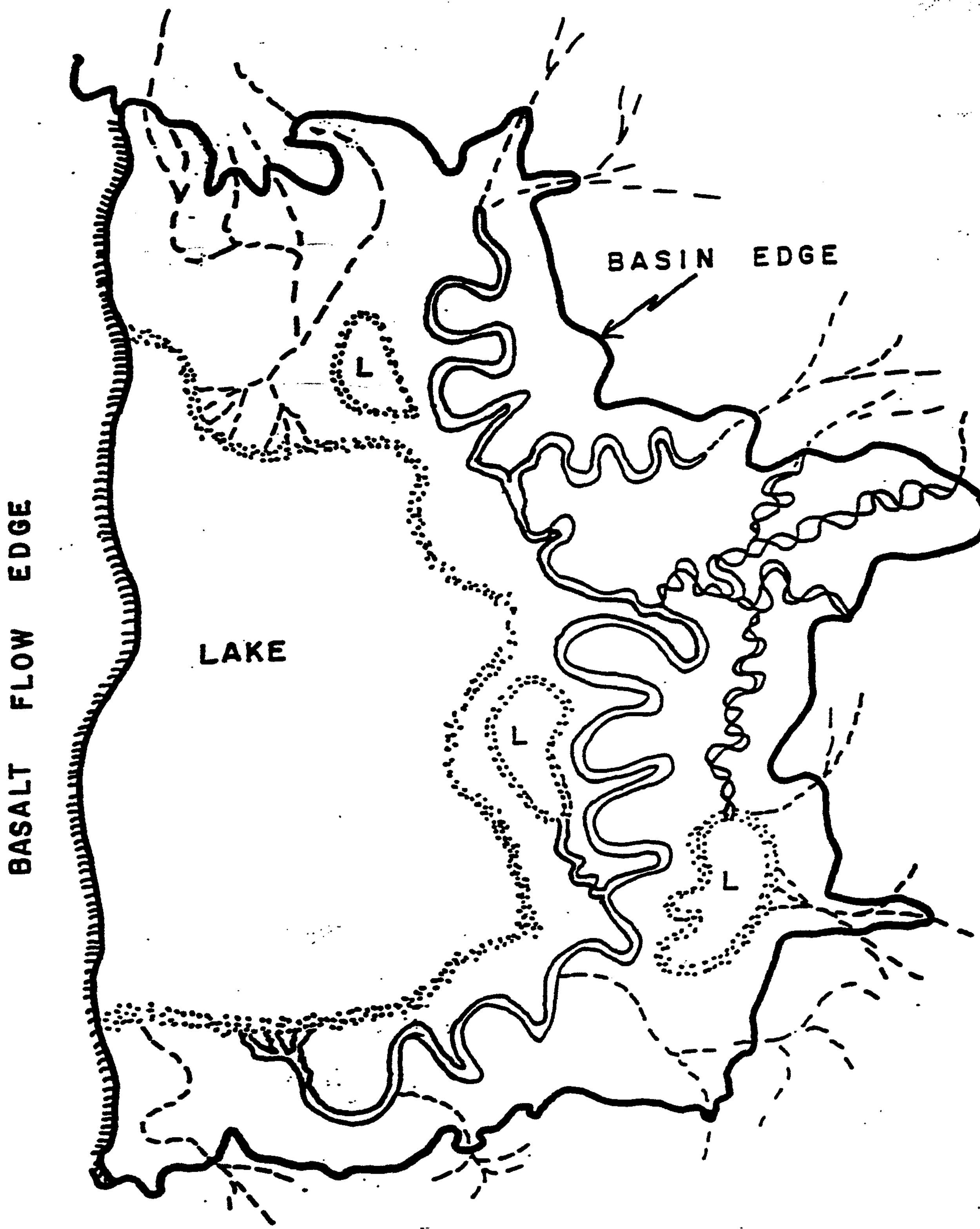

Figure Three-- Conceptual illustration of Potential paleo-setting in Moscow during basalt emplacements.

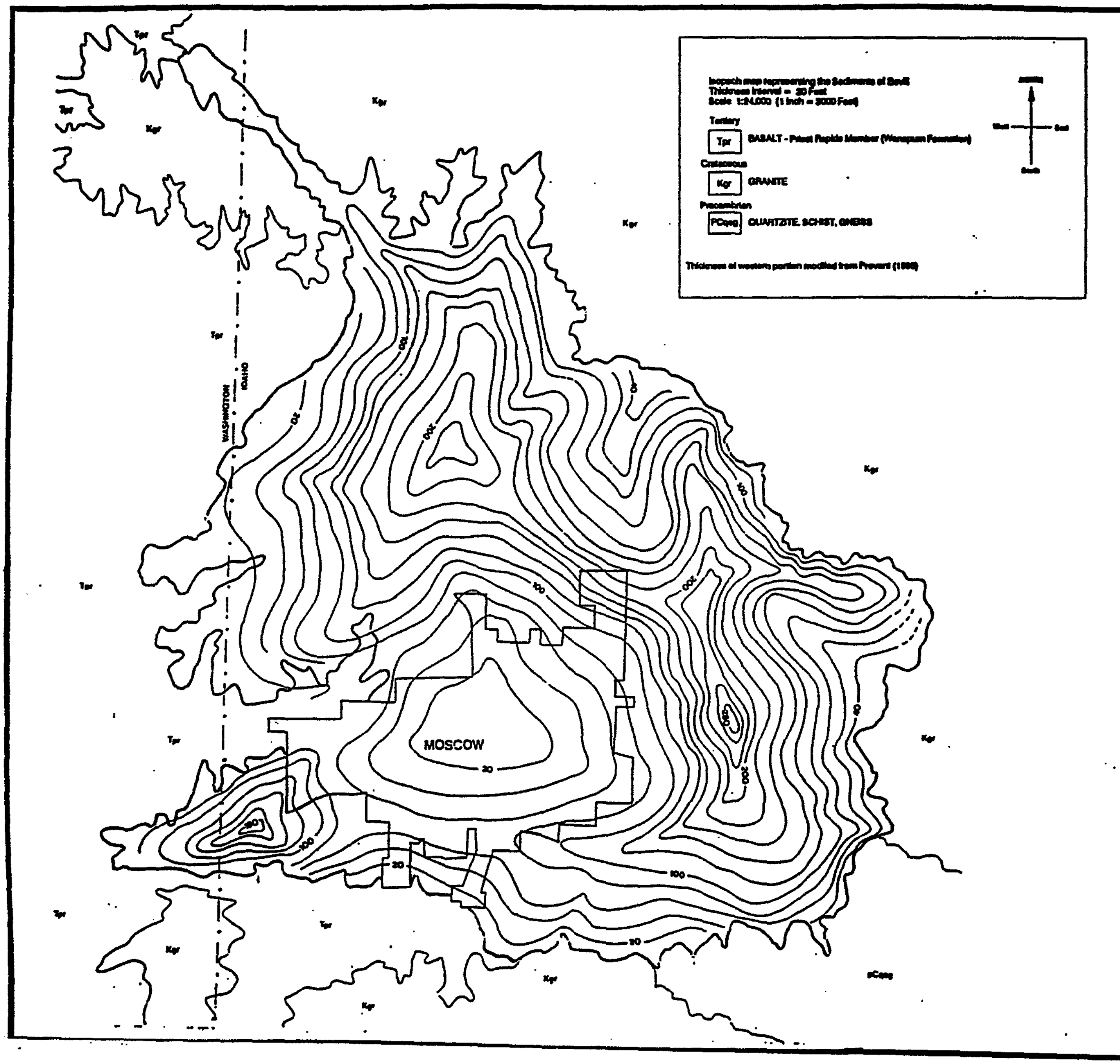

Figure Four-- Isopach Map representing the Sediments of Bovill in Moscow, Idaho. (From Pierce, 1996).

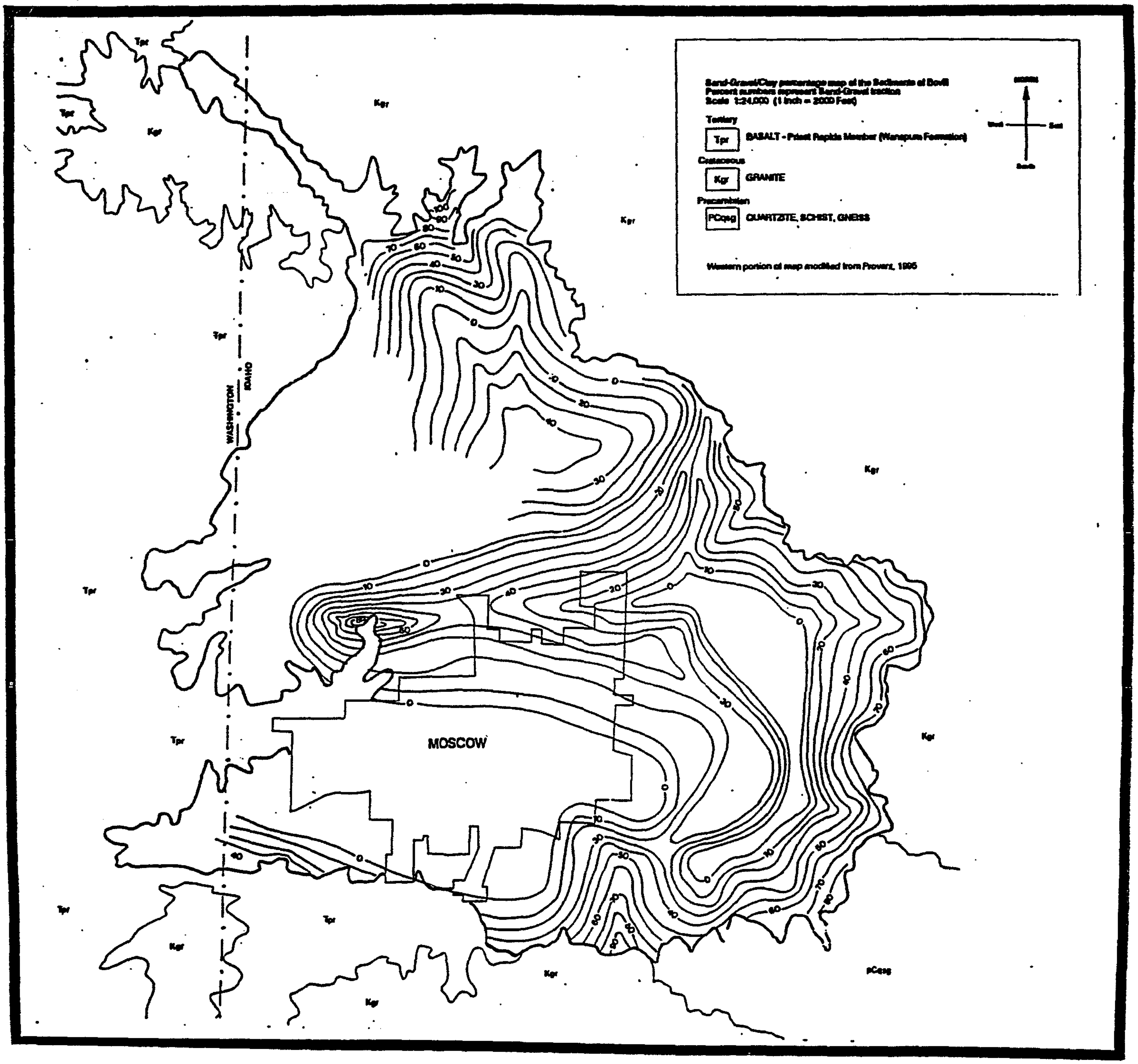

Figure Five-- Sand-gravel/clay percentage map of the sediments of Bovill, Moscow, Idaho. (From Pierce, 1996).

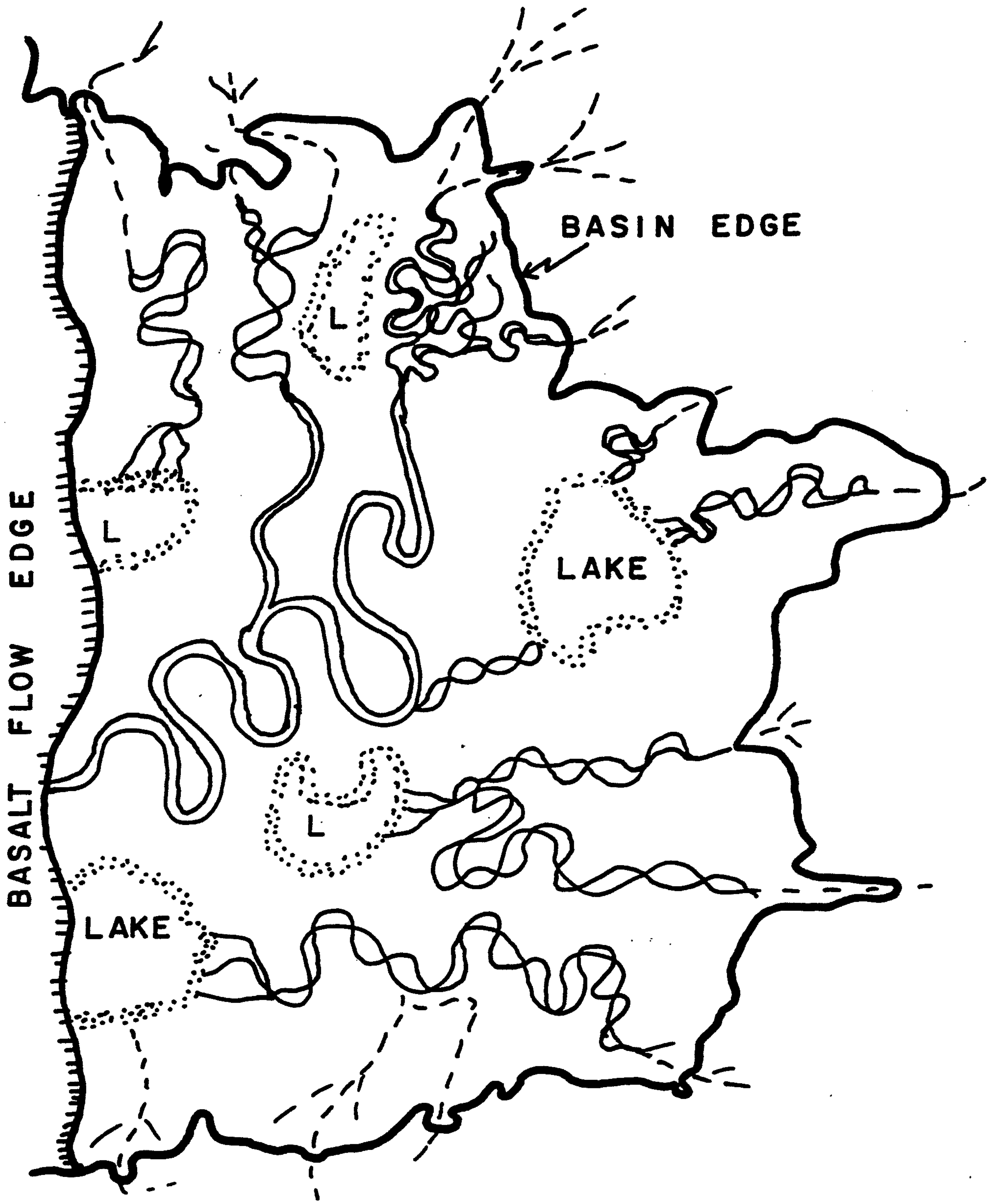

Figure Six-- Conceptual illustration of a possible depositional setting for part of the sediments of Bovill.

must be considered. A portion of the evidence is presented in list form.

1) Late Grande Ronde, pre-Priest Rapids subsidence caused several flows attempting to enter the Moscow-Pullman basin from the west to pinch or thin out over this area.

2) One member of the Wanapum Formation (Roza Member) can be mapped at the surface and thinning from 200 feet in thickness to zero across this zone is documented. Thinning or pinching out of late Grande Ronde and early Wampum flows along the "zone" indicates that the Moscow -Pullman basin was in part elevated from the Plateau proper during a major part of basalt emplacement history.

3) The area in discussion approximates the proposed edge of continental material and is in a "zone" connecting granitoid rocks at Granite Point along the Snake River on the south to Precambrian? rocks at Albion on the north.

4) Well documented stratigraphic marker horizons in the basalt sequence that were once horizontal drop rapidly in elevation to the southwest across the "zone" under discussion and indicate post-Priest Rapids deformation along that "zone".

5) Well documented near vertical dike swarms of Grande Ronde Basalt located south of the area project into the "zone" and could be present in the subsurface.

6) Gently folded post Priest Rapids flows southwest of Pullman have axis orientations that trend Northwest and project into the "zone" under discussion.

7) Modern streams in parts of Whitman County follow and parallel the Northwest trending "zone".

Figure Seven is a conceptual presentation with and without a basement high. The drawings are at right angles to the zone and are based on basalt stratigraphic relations known to exit before post Priest Rapids deformation. Both illustrations do not include potential dike swarms nor do they illustrate post Priest Rapids deformation. Although the true nature of the subsurface across the "zone" it is not clear, there is enough evidence to indicate a subsurface geologic boundary that defines the western end of the Moscow-Pullman basin.

HOLOCENE EVENTS AND SHALLOW RECHARGE

In Moscow, stream erosion and deposition has still not adjusted to the disruption caused by basalt emplacement and associated deposition of sediments. Loess deposition in the Pleistocene further slowed that adjustment. Drainages in the

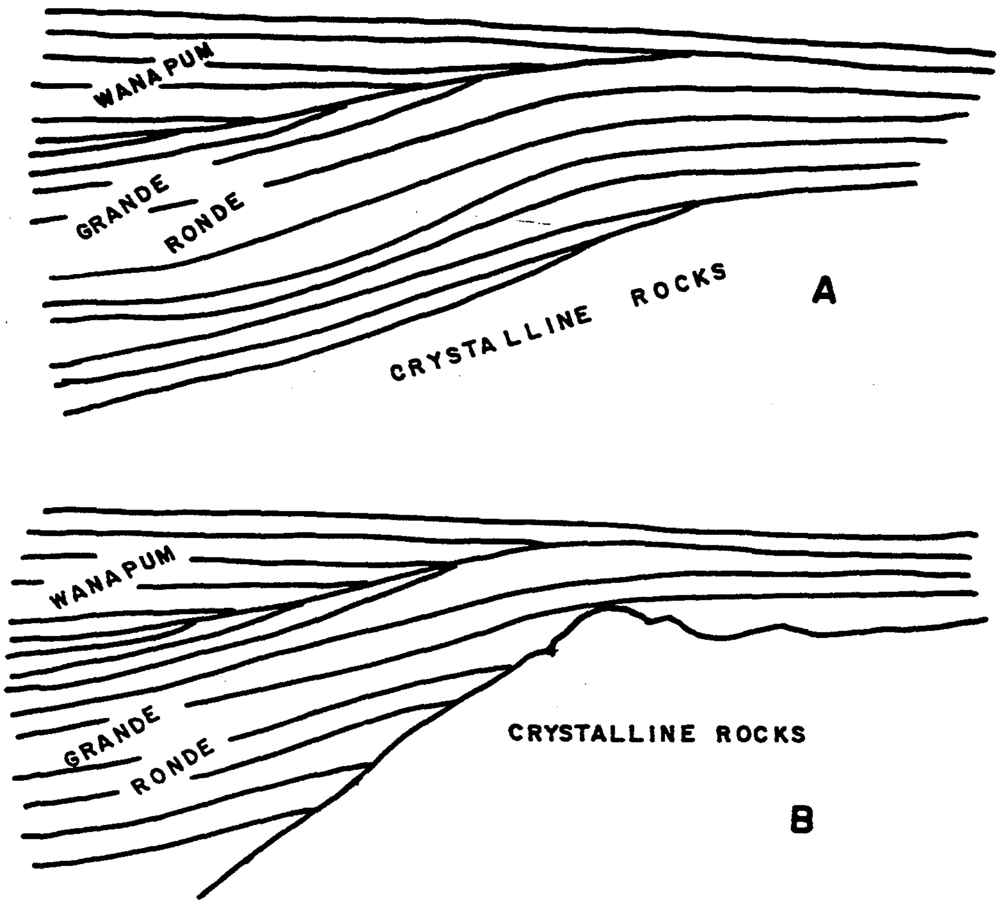

Figure seven--Conceptual illustrations of east-west views of stratigraphic relations across potential barrier before post Priest Rapids deformation. (A) assumes no basement high, whereas (B) assumes a small basement high.

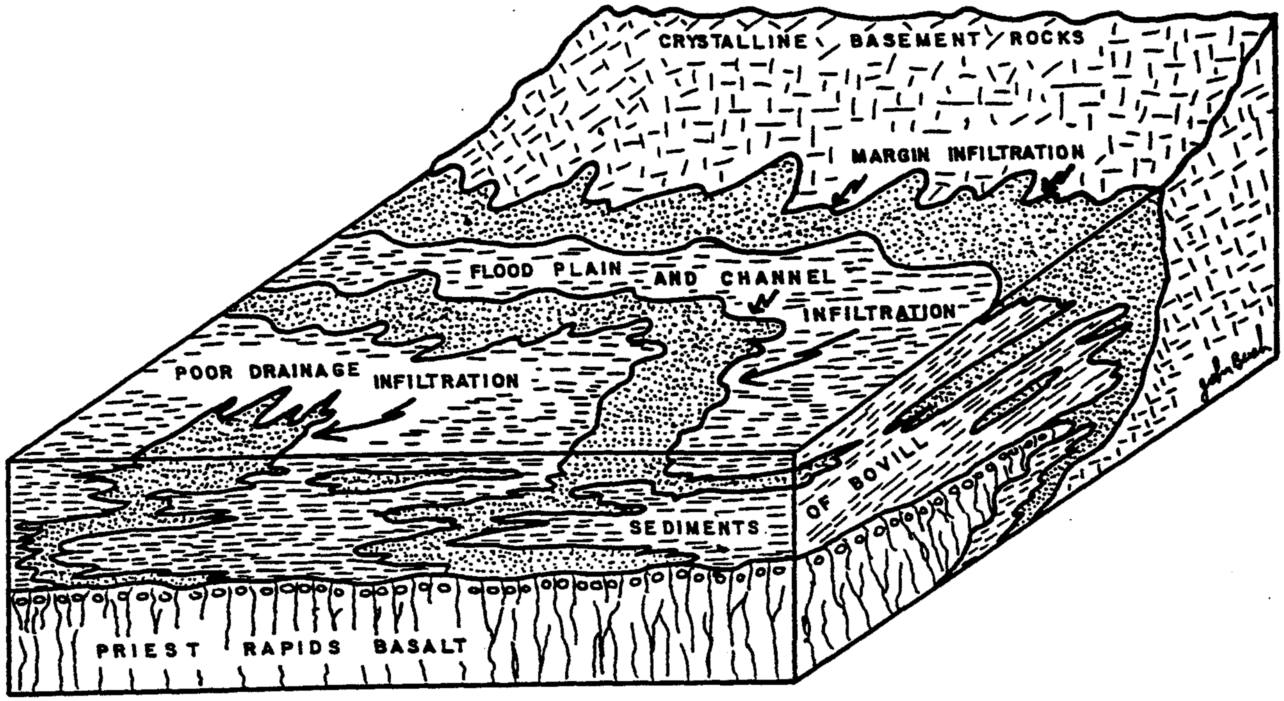

Figure Eight-- Facies model for the Sediments of Bovill in Moscow, Idaho, illustrating potential infiltration methods.

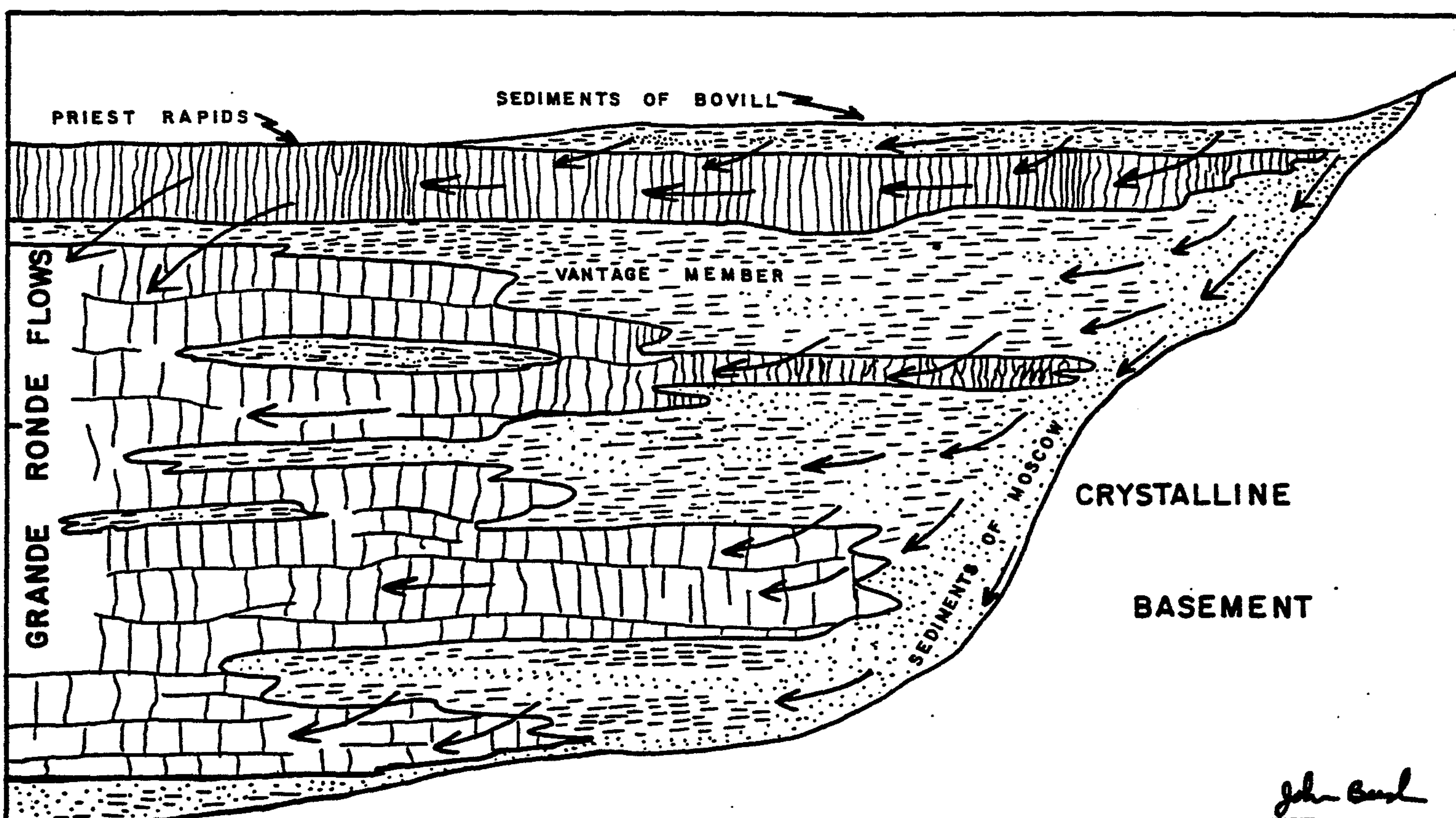

Figure Nine--Conceptual model of groundwater flow for the eastern end of the Moscow-Pullman basin.

eastern part of the basin appear to follow the basalt-granite contact and the distribution of the coarse-grained facies in the sediments of Bovill. Non-bedrock hills with thick loess in western Moscow are cored by clay-rich sequences of the sediments of Bovill, whereas the eastern most hills within Moscow consist of coarser units overlain by thin loess. In general erosion has occurred in the least resistent coarse-grained units and present day streams follow older post Priest Rapids channels and trend around the more resistent clay hills.

Pre-civilization flooding in Moscow probably occurred at least every 2-2.5 years, with wetlands existing for months during some years. Infiltration occurred and occurs into the sediments of Bovill in areas proximal to basement highs and into the westward trending channel deposits(Fig.8). These coarser units, although irregular, are likely to be connected vertically, and they also occur as laterally sinous channel sands that extend westward into and beneath the clay units. Excavations have shown that these coarser units are in places, in contact with scoriaceous and fractured flow tops of the Priest Rapids Member. Vertical recharge, including movement into deeper sediments and basalts is likely in eastern Moscow, whereas lateral recharge into the upper aquifer is more likely in western Moscow.

The vertical recharge in eastern Moscow is probably not "sieve like". Instead the coarse units get filled creating semi-confined perched aquifers, which over time leak further into the subsurface. The fact that the city is engineered to keep the flood plains from flooding may have cut off this gradual but continual recharge method. Protection from flooding moves the water out of the basin causing the stream volume to drop rapidly in short time. Thus, the modern channels following the coarse-grained units in the sediments of Bovill have little time to provide opportunities for seepage further diminishing recharge.

DEEP AQUIFER RECHARGE

Recharge through the sediments of Bovill clearly affects the upper aquifer. What about the Grande Ronde aquifer? Note that earlier Latah sediments were deposited in the same fashion as the sediments of Bovill. Water movement in the older sediments is likely to be also controlled by the distribution of the coarse-grained units similar to ground water movement in the sediments of Bovill. The basalt flows were emplaced from the west with highly fractured and scoriaceous flow fronts and tops expected in the Moscow area. Where the sediments are clay-rich they can act as aquitards and were coarse-grained they can act as channel ways for movement. The channel ways would be more numerous to the east where water from highlands would infiltrate and feed the westward trending paleo channels. Natural gradient in these paleo channels is westward.

In the near future it will be necessary to determine the subsurface configuration beneath Moscow, as well as those areas where potential paleo-channels to the north and northwest could connect the basin to areas outside its borders.

CONCLUSIONS

The models presented herein for the subsurface geology and the recharge in the Moscow basin is a framework for thinking. The geologic model presented is a reasonable approximation of reality and is based on geologic data available from the subsurface, outcrops, regional geologic history, and geologic mapping; the geologic model presented herein for the subsurface is a reasonable approximation of reality. Additional data will refine it although it may not ever be completely accurate because of economic and technological limitations. In mathematical terms, for those who need a number, the geologic model is believed to be in the 90% probability range of being correct. The major weakness is the lack of depth to basement data in key areas.

The recharge model presented assumes the geological model is accurate enough to be useable. The recharge model built on the geologic model simply states that recharge from our flood plains and poor drainage areas into the sediments of Bovill and upper basalt aquifer is highly likely. Extending the model, it is reasonable to assume that over time our lower aquifers have been recharged by the same method. This model has not been tested hydrologically nor does the model define rates except that upper aquifer recharge should be quick by human standards and lower aquifer recharge may be long by human standards.