PRELIMINARY GEOLOGY OF THE NORTHWESTERN PORTION OF CANYON COUNTY, IDAHO

IWRRI Technical Report 200510

Prepared for the Idaho Department of Environmental Quality

by

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April 20, 2005

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) promulgated a rule on 12/7/2000 that requires a maximum contaminant level (MCL) compliance at a concentration of zero pCi/L for radionuclides in community water systems. The Idaho Department of Environmental Quality (IDEQ) adopted this rule effective on 3/15/2002. Clearly, the source and distribution of water-born radiation must be well understood in order to effectively implement these new regulations.

A number of ground-water quality problems exist within Canyon County, including locally elevated levels of radionuclides, naturally occurring concentrations of arsenic, agriculturally caused nitrate loading, and thermal water. Sampling by IDEQ has revealed strongly elevated levels of radiological constituents in ground water near Caldwell. The geographic extent of this problem is not fully known, and the source of the radionuclides not understood. IDEQ requested that the Idaho Water Resources Research Institute (IWRRI) develop the first phase of a multi-year study that will result in an understanding of the geological sources and distribution of radionuclides that affect ground water as well as a hydrogeological characterization of aquifers in the study area. This report summarizes results from the geological portion of this initial study.

PURPOSE

This study was undertaken to aid in understand the source and distribution of elevated radionuclides in ground water in northeastern Canyon County.

OBJECTIVES

Our objective is to provide DEQ with information regarding radionuclide distribution, concentration in ground water.

WORKING HYPOTHESES

A number of mechanisms could contribute radionuclides to ground water in northeast Canyon County. Fundamental to all is the need to have a radioactive element source with which ground water associates. Radioactive minerals could (1) reside at an up-gradient location and interact with water passing through, (2) they could be a clastic component of the aquifer in which the water resides, or (3) the radioactivity could travel in solution by ground water at levels below detection and then concentrate at certain locations due to changes in redox conditions. A large quantity of uranium and thorium-bearing minerals occur in nature; Appendix 1 lists commonly occurring varieties of both uranium- and thorium-bearing species. Figure 1 shows the Uranium decay series; most alpha and beta emitting reactions also emit gamma rays as part of the decay process. Some of the more common radiogenic minerals, like uraninite and thorite are much denser than the common rock-forming minerals so tend to concentrate during stream flow within more energetic portions of an aqueous flow regime; a process analogous to the formation of placer gold occurrences.

In the first case, external contamination, at least two factors are required to explain concentrated radionuclides in ground water; a source for the radioactivity must be present up gradient, and some mechanism that concentrates the contaminated water in the aquifer. These requirements seem difficult to explain in northeastern Canyon County.

Case 2, clastic radioactive minerals in the aquifer is a possibility. If this were the source of radionuclide contamination I would expect the water-borne radioactivity to be distributed unevenly because of the potentially inhomogeneous distribution of the radioactive minerals in the host strata. The distribution of silt- and sand-size radioactive rock fragments would be channeled within the higher energy portions of the sequence if concentrated by fluvial processes. The degree of radionuclide concentration in ground water should then be a function of two factors; the quantity of radiogenic minerals in a given area, and ground water flow rate. Flow rate is a factor because it dictates the residence time that water can interact with the radiogenic minerals. Either slower flow rates or greater quantities of radiogenic minerals would result in increased radioactivity in ground water. The type, concentration, and distribution of radiogenic minerals in the host strata are the most critical elements to understanding the possible occurrence of this mechanism.

Movement of radionuclides dissolved in ground water, case 3, is an appealing concept. Ground water could transport low concentrations of radioactive constituents, and upon encountering a reducing environment, precipitate and form secondary uranium minerals such as carnotite. Reducing environments can be created by a number of mechanisms that reduce the concentration of free oxygen. These include vegetation rotting or sediment diagenesis. Oxidized near-recharge-source ground water traveling down-gradient would likely encounter reducing conditions. Roll-front uranium deposits form in this fashion; secondary uranium minerals precipitate where uranium-bearing ground water encounters reducing conditions. Decaying vegetation commonly occurs in Idaho Group sediments. Well logs commonly mention the occurrence of decaying wood and leafy material, and sulfurous-smelling ground water is common. Old, "Lake Idaho" shore lines where trees and bushes accumulate could be one such environment.

A comprehensive analysis of the radionuclide issue in northeast Canyon County must consider all of these possibilities. A complete understanding of possible contamination due to concentrated clastic radiogenic minerals must start with an accurate description of the three-dimensional morphology of host strata. Unfortunately, driller's well logs are generally not of sufficient quality to accomplish this. Additional work required to further understand these strata and their potential impact should include sampling and analysis of cuttings from newly drilled wells. This work must await analysis of water samples from the second, geochemical, phase of this study in order to help concentrate the collection of samples to documented problem areas. If redox boundary conditions are responsible, a comparative analysis of radiometric well logs with lithologic logs would be helpful.

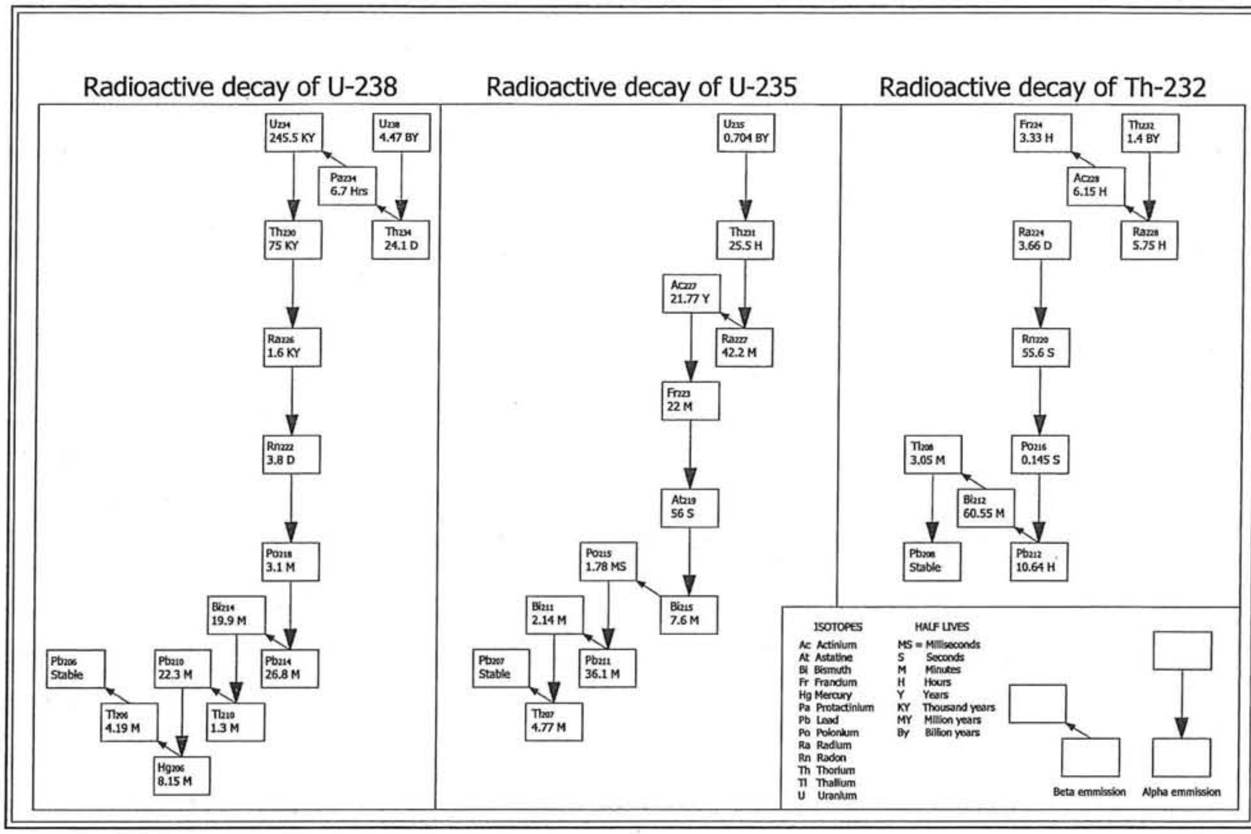

Figure 1: Chart showing the decay series for uranium 238, uranium 235, and thorium 232 (created from various web-based sources).

METHODS OF STUDY

Sedimentary strata in the study area are generally flat lying and poorly exposed. These two factors reduce the usefulness of surface mapping in understanding the problem. A critical analysis of data from water well logs is therefore one of the few means of understanding the type and distribution of subsurface strata. The geological portion of this study has therefore relied heavily on data from these logs, and to a lesser degree, on analysis of surface exposures. Correlations of similar sediment types at similar elevations between wells have resulted in a three-dimensional interpretation of critical subsurface sedimentary units. I have also incorporated geological mapping by Othberg (1994) and stratigraphic work by Otto and Wylie (2003).

REGIONAL GEOLOGY

Northeastern Canyon County lies along the northern margin of the western Snake River Plain (WSRP), an intracontinental rift basin formed in Neogene time (Wood and Clemens, 2003). Fine-grained siliciclastic sediments of the Idaho group, described by Wood and Clemens, 2003, Wood, 1994, and Othberg 1994, fill the basin and reach a thickness of over 6500 feet (Wood and Anderson, 1981). Several deep gas and hydrothermal exploration wells in the WSRP, discussed by Kirkham, 1935, Newton and

Corcoran, 1963, Wood and Anderson, 1981, and Wood, 1994, show that Miocene basalt underlies a several thousand-foot-thick section of Idaho group strata. Dissected gravels from extinct river systems lie disconformably above the Idaho Group sediments and cap terraces throughout the WSRP (Malde and Powers, 1962; Malde and Powers, 1972; Othberg, 1994). These gravels are commonly exposed at surface, or directly underlie a mantle of surficial sediment. Othberg (1994) correlates similar gravels immediate south of the study area with the Ten Mile gravels.

PROJECT AREA GEOLOGY

A lack of exposed strata in the project area inhibits a comprehensive understanding of the surface geology. In general three types of strata are exposed at surface; all are younger than the Idaho Group. From top down these include: fine-grained fluvio-lacustrine and eolian sediment, basalt lava, and coarse-grained stream gravel. The basalt lava, dated at 799 thousand years (Othberg, 1994), and the underlying gravel fills channels carved into the upper sediments of the Idaho Group. Othberg (1994) mapped the entire area as terrace gravel capped by 1 to 2 meters of loess. Lithologic logs from drill holes and field observations in the study area show that the gravel is locally overlain by over 50 meters of fine-grained sediment.

STRATIGRAPHY

PRE-IDAHO GROUP ROCK UNITS

Crystalline rocks of the Idaho Batholith are exposed in the foothills northeast of the study area. They lie on the up-thrown western sides of north-northwest trending normal faults northwest of the study area, against Idaho group and younger strata. No crystalline rocks are exposed in the study area; the deepest well terminates 1010 feet below surface and is in Idaho group sediment to the bottom (Caldwell monitoring well in the SENE of Sec. 15 T4N R3W). One well, in the Willow Creek drainage, encountered granite at a depth of 363 feet. This well was drilled on the up-thrown northeasterly side of a fault. Regional stratigraphic relationships suggest that Miocene-age lava flows may also occur below the Idaho Group sediments. Granitic rocks northwest of the study area provided a source terrain for sediments carried by streams into the Pliocene Lake Idaho basin.

MINERALOGY OF POTENTIALLY RADIOGENIC COMPONENTS

Few radiogenic mineral species in crystalline rocks of the Idaho batholith occur in high enough concentrations to provide the quantity of radionuclides present in some northeast Canyon County ground water. Bedrock sources for radiogenic minerals, such as veins containing pitchblende (uraninite) or thorite, have not been noted in the these granitic rocks.

A number of mineral districts within the batholith in central Idaho, however, contain elevated concentrations of the radioactive minerals such as uraninite, thorite, and monazite. These districts include Lemhi Pass, Stanley, and Boise Basin (Staatz, 1979;

unpublished mapping by Otto, 1979). The Pearl mining district in the upper Willow Creek drainage northeast of the study area contains mesothermal quartz-arsenical sulfide veins. These veins were not sampled and radiogenic minerals have not been identified. Veins similar to these, however, in the districts to the northeast contain radioactive minerals, suggesting the possibility that the Pearl veins may locally contain a similar mineralogy. Willow Creek is an ancestral first-order stream that probably drained the Pearl area during and certainly after Lake Idaho time. This drainage could have shed radiogenic constituents into sediments that now underlie the study area.

IDAHO GROUP SEDIMENTS

Idaho Group sediments in the study area consist of fine- to medium-grained sand, clay-rich silt, and interbeds of and local accumulations of pebble conglomerate. Work by Otto and Wylie (2003) in the adjacent Greenleaf area identified at least four laterally extensive and regionally correlative clastic sequences in sediments of the Idaho Group which I named from top down A1 through A4. The clastic intervals include conglomerate, medium- to coarse-grained arkosic sand, and black sand. They occur as discrete tabular sequences within clay-dominant strata, and probably accumulated from streams meandering across the muddy lacustrine sediments during low lake levels. Their continuity and increased grain size make them productive aquifers. I have attempted to correlate strata in the study area to the Greenleaf section with some limited success. The Idaho Group sediments are not exposed in the study area so the following lithologic interpretations were derived from well logs.

In general, the study area section is sandier and includes more interbeds of gravel, which is probably an expression of a shorter distance to the sediment source. Conglomerates and coarse sands of the Idaho Group exposed in the upper Willow Creek drainage suggest an abrupt facies change between the upper and lower stretches of the drainage. Similar facies relationships along the Boise front have been described in detail by Squires and others (1992) and Wood and Clemens (2003).

The A2 clastic sequence of the Greenleaf area correlates in elevation with coarser clastic material north of the Boise River on section K (Plate 6). Several wells penetrated a second unit of coarse clastic strata lower in the holes, which may correlate with the A3 sequence. Arsenic is concentrated above the EPA year-2006 MCL of 10 µl in water samples from the A1 and A2 sequences but occurs only in trace amounts in A3 and A4 (Otto and Wylie, 2003). Perhaps these possible stratigraphic correlations could be refined using water chemistry. Wells in the study area are not deep enough to address possible correlations with the lower two clastic sequences.

MINERALOGY OF POTENTIALLY RADIOGENIC COMPONENTS

The only way to evaluate Idaho Group strata for the possibility of containing clastic radiogenic mineral fragments would be to sample and analyze cuttings from drill holes as they are drilled. This type of work was not performed. Black sands, described in many of the logs may be fragments of basalt or placer lag deposits of high-density minerals such as magnetite and ilmenite; they could also potentially contain radioactive minerals such as pitchblende, thorite, and monazite. Some of the silty lacustrine beds and arkosic sands might contain silt-fraction K-feldspar with radiogenic potassium.

POST-IDAHO GROUP ROCKS AND SEDIMENTS

BASALTIC LAVA FLOWS

Basaltic vents, including Christmas Mountain, Initial Point, Kuna Butte, and Powers Butte, form a northwest-southeast alignment of volcanoes between Mountain Home and Marsing (Othberg 1994; Wood and Clemens, 2003). A basaltic lava flow dated by Ar/Ar at 0.799 ± 0.095 Ma occurs in the Caldwell area, and probably flowed from one of these vents (Othberg 1994; Figure 2). Today the lava forms an inverted topographic feature, a prominent ridge between Nampa and just north of Caldwell. This horizontal and vertical distribution of lava and the vertical stratigraphy of adjacent sediments suggest that it flowed from southeast to northwest in a gravel-bottomed valley. Othberg (1994) suggests that eruption of these lavas caused a major westward diversion of the Snake River. He further suggests that Indian Creek now occupies the same valley followed by several lava flows, including the Caldwell flow, and may have been a channel of the ancestral Boise River. Also likely is the possibility that the paleo channel is that of the Snake River prior to its westward migration.

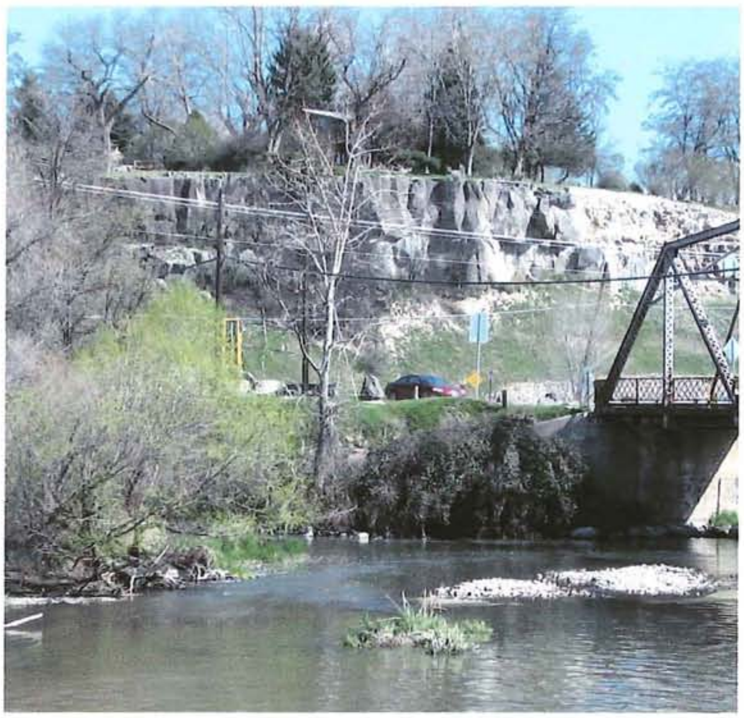

Figure 2: Outcrop of 800-thousand-year-old basalt lava flow in Caldwell.

<u>*Mineralogy of potentially radiogenic components*</u>

Basaltic lavas generally do not contain constituents that would supply radioactivity to ground water.

GRAVEL SEQUENCE

A sequence of fluvial gravel occupies much of the section in the study area area. Othberg (1994) refers to this sequence as the Sunrise terrace, interprets it as the third terrace level above the modern Boise River, states that it lays approximately 35 meters above river level, and is late middle Pleistocene age. He indicates that the gravels are covered by up to 2 meters of loess. This interpretation suggests that the gravel unit lies above the Caldwell basalt flow (Table 3 in Othberg, 1994). Well logs show that the Sunrise-Terrace gravels exposed at surface throughout much of the study area correlate with gravel exposed in Caldwell below the lava flow. Plate 1 shows the plan distribution of the gravel and Plates 2 and 3 its overall thickness and shape of its bottom surface. Plate's 4, 5 and 6 show the well to well stratigraphic correlations. The gravel occurs from a top elevation of 2626 feet (Vanderway well, NWSE section 25 T5N R2W; 82.6 meters above river level at Caldwell) to a bottom elevation of 2304 (Simplot well, NESE Section 19, T4N R3E; 15.5 meters below river level at Caldwell). It has a maximum-known thickness of 153 feet (Vanderway well, NWSE section 25 T5N R2W) and is locally covered by up to 40 meters of fine-grained sediments. Field evaluation and well logs of the capping sediments shows that they represent an eolian and lacustrine environment of deposition (i.e. Dedore well, SENE Section 21, T5N R2W).

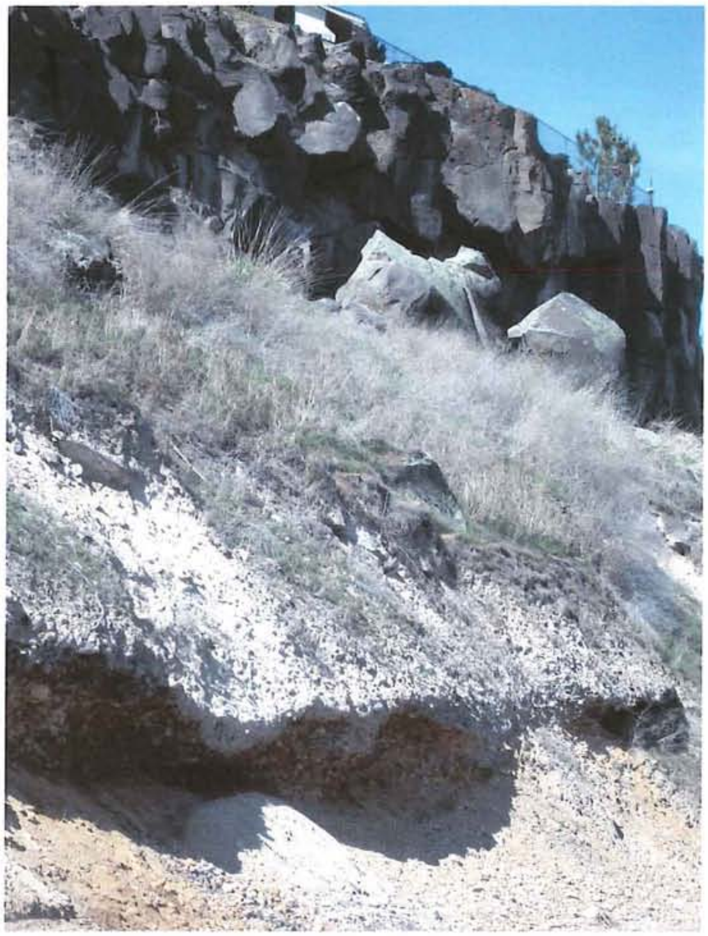

Figure 3: Photograph of Willow Creek gravel sequence exposed beneath the basaltic lava flows near Caldwell.

The gravel lies beneath the Caldwell basalt flow and disconformably above sediments of the Idaho group. It forms two stacked sequences of cobble to boulder sized fragments in a coarse-grained sand matrix. The two sequences are generally separated by a section of finer grained sediments, but locally, the two are amalgamated into one thick, continuous sequence (see the Sid Bright well, NESW Section 20, T5N R2W; Section B, Plate 4). Exposures of the gravel along the Boise River in Caldwell show that it is cemented by iron, and some of the well logs also indicate strong induration (Figure 4). The thickness, distribution, and grain size show that the gravel sequence was deposited by a large fluvial system. Correlation diagrams of Plates 4, 5 and 6 show that the gravel pinches out abruptly to the northeast and northwest, but continues to the south. The base elevation of the sequence, nearly 50 feet below the present level of Boise River, its top elevation, over 260 feet above the Boise River, and its stratigraphic position below the basalt lavas that

Figure 4: Close-up photograph of Willow Creek gravel outcrop; note the ferrugenous cement in the finer, sandy matrix between the cobbles. Also note the gray-colored manganese stain.

traverse diagonally across the entire present Boise River valley, show that the gravel could not have been deposited by an ancestral Boise River. Rather, they may represent a paleo Snake River channel that followed the present-day Indian Creek drainage. Perhaps this large arcuate accumulation of gravel below Sunrise Terrace represents a major bend in the paleo river channel where it carved into the Idaho Group sediments along the northeastern margin of the Snake River Plain. Similar meander scars occur along the Snake River today between Ontario and Weiser. Another, more abstract possibility, is that the paleo drainage could have continued along the present-day axis of Willow Creek to Horseshoe Bend, thence downstream through Emmett. In order for this possibility to have happened the low mountain range between Black Canyon Reservoir and lower Willow Creek would have had to form in the last 800 thousand years, an unlikely possibility.

Agricultural irrigation probably provides most of the ground water that recharges the gravel, indicated by Plate 1, which shows an elevated water table over the agricultural land and indicates an inclination generally to the south. The base elevation of most of the gravel sequence lies above the elevation of the Boise River, so the river cannot supply this water. A canal that comes from Black Canyon reservoir, on the Payette River, supplies irrigation water to the upper, northern edge of the area underlain by the old gravel sequence, which is then distributed by ditches over most of the study area. This suggests that much of the ground water in the gravel is supplied by the Payette River.

Several wells near Caldwell, shown on Plate 1, have artesian heads. Some of these wells terminate in the gravel sequence and some pass through it. The positive heads have generally been attributed to upward flow from confined aquifers in the Idaho Group (Hutchings and Petrich, 2002). As discussed above, ground water in the old gravel sequence probably migrates from the agricultural land in the northern part of the study area down-gradient to the south. The Boise River is presently dissecting the old gravels so it is likely that the ground water in the old gravel, derived from the Payette-River, discharges to the Boise River. It is important to note that if this is true, radionuclide-contaminated ground water hosted by the gravel communicates directly with the Boise River and down-gradient shallow aquifer that it recharges.

<u>Mineralogy of potentially radiogenic components</u>

The present level of water sampling does not have enough resolution to determine if the old gravel sequence is the source of radionuclide concentration in northeastern Canyon County. All contaminated samples in this area of which I have record have come from wells that penetrate the gravel, which forces a serious evaluation of the possibility that the gravels are the source. As discussed above, at least two potential modes of uranium occurrence are possible; detrital placer accumulations that contain uraniferous minerals, and secondary growths of uranium mineral species such as carnotite. Surface water that recharges the gravel aquifer probably does not contain detectible radionuclides, and further, the ground water may have only been in the aquifer since after construction of the canal network in the late 1800's and early 1900's. If true, this temporal relationship shows that locally elevated concentrations of radionuclides in ground water is a direct function of locally concentrated radioactive minerals in aquifer-forming strata. The question remaining relates to their mode of occurrence: do these minerals occur as detrital mineral fragments in the strata, did they grow in situ as secondary replacements, perhaps along redox fronts, or some other mechanism yet to be described?

EOLIAN AND FLUVIO-LACUSTRINE SEDIMENTS

A variably thick section of locally indurated, fine-grained sediment caps the Willow Creek gravel sequence and the basalt lavas. Stratigraphic correlations from this study (Figure 5; Plates 4-6) and by Otto and Wylie (2003) show that the section occurs on both sides of the Boise River flood plain. Well logs in the study area show thicknesses greater than 50 meters (Figure 5). The section near Greenleaf occurs both above and below the

Willow Creek gravels and is locally over 20 meters thick. Bedforms displayed in outcrop show that it was deposited by a combination of wind and streams. The primary agricultural substrate in most of the farmland north of the Boise River floodplain is composed of these strata.

The lithological similarity with Idaho group sediments indicates that Idaho Group strata were the sediment source. The striking similarity of the reworked top of the Idaho Group compared with this younger section make it nearly impossible to define an age-based contact between the two where the intervening basalt lavas and the Willow Creek gravels

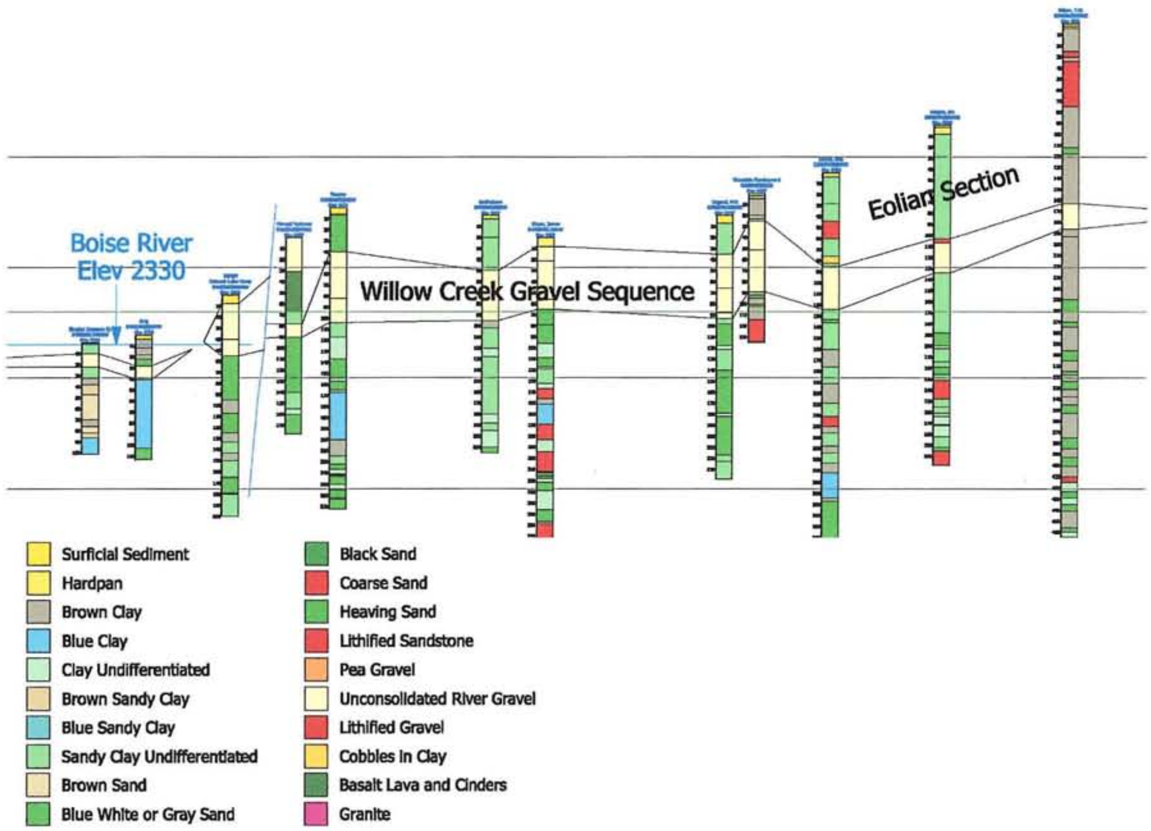

Figure 5: Well-to-well correlation diagram showing distribution and thickness of the eolian section with respect to the Willow Creek gravel sequence. See section J, Plate 6 for reference.

are absent. Their thickness and presence both above and below the gravel and basalt section indicates that the unit represents a long period of reworking of Idaho Group sediments. Because of the lithological similarity of strata representing a broad time period, some of the finer grained strata mapped in the lower Snake River plain may be temporally miscorrelated; published geologic mapping, including plates 1-3 of this report, should be used with due caution.

Figure 6: Photograph showing large-scale crossbeds probably formed from eolian activity. Note surface coating of gypsum.

Occurrence of potentially radiogenic components

Nearly all of the post-basalt eolian section lies above the present water table, so probably does not contribute to concentrations of radionuclides. Surface coatings of gypsum on outcrops show that evaporation of a relatively high volume of calcium-laden water must have taken place, and additionally shows that the unit is thoroughly oxidized.

DISCUSSION

Uranium occurs in two valence states, U^{4+} and U^{6+}. Natural weathering of rocks will convert uranium into the oxidized +6 state. This ion is soluble in groundwater, unlike the reduced U^{4+} species. The oxidized ion is stable and uranium can be transported by groundwater so long as the groundwater remains oxidizing. When the oxidized ions encounter reducing conditions they will precipitate, forming secondary accumulations of uranium and other associated minerals, including molybdenum, vanadium, selenium, and arsenic (from web-based sources) . Sandstone-hosted uranium deposits, known as roll-fronts, form by the precipitation of uranium from groundwater. Figure 7 shows a schematic of a typical roll-front uranium occurrence. The Willow Creek gravel sequence hosts the hydro-geological conditions necessary for roll-front-style uranium occurrences.

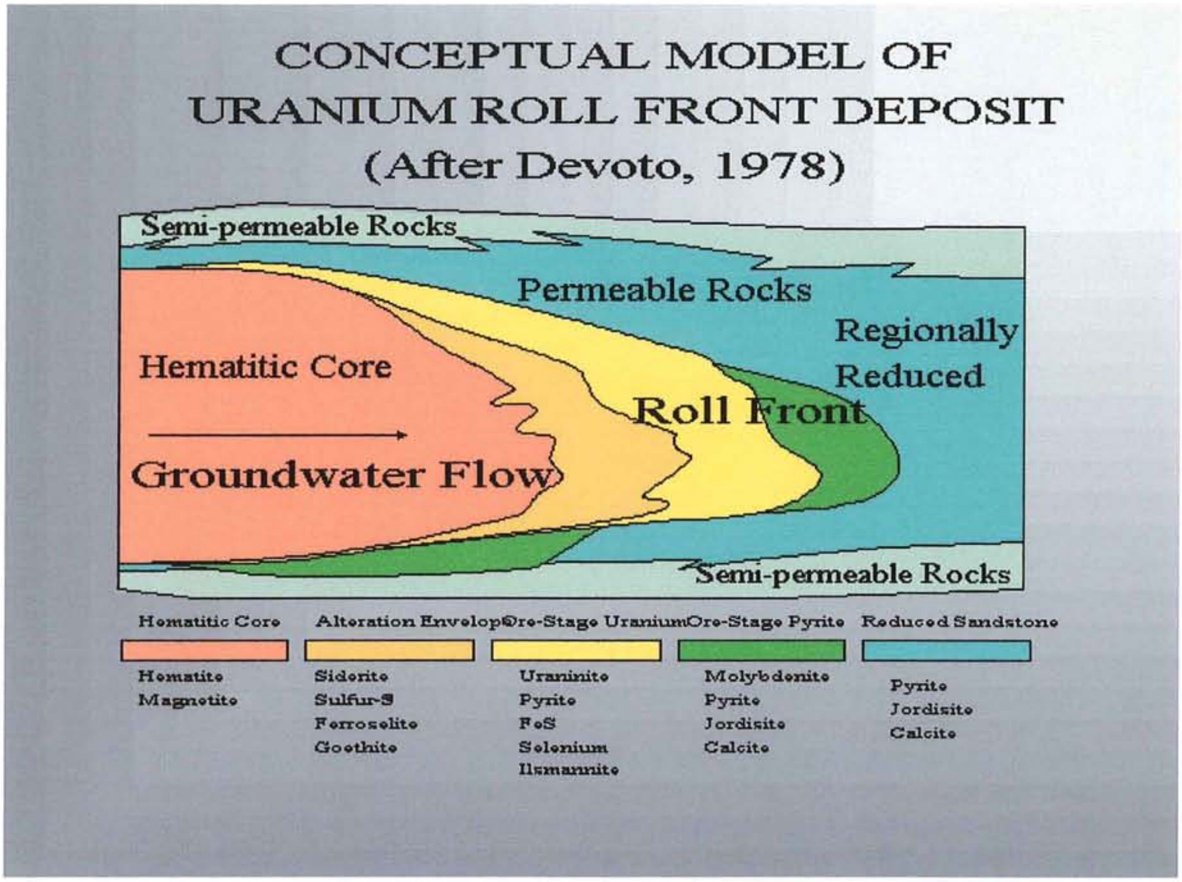

Figure 7: Conceptual model of a uranium roll-front deposit (from http://www.wma-minelife.com/uranium/mining/rllfrnt1.html; courtesy of John Hamrick of UMETCO Minerals *Corporation*).

The depositional and erosional history of the Willow Creek gravels may shed light on their hydrologic history, and perhaps, on an association with concentrations of radionuclides. There have been a couple of geologic events and numerous climate fluctuations that may have dramatically affected the ground water level in these gravels over the past million years. Each time the ground water table changes significantly there is also the probability that redox interfaces will move. If the elevated concentrations of radionuclides in the study area are controlled by redox boundaries then the specific locations of these concentrations could move along with the redox interface as the ground water table changes. I do not know how rapid or sensitive this type of system could be, but see a possibility that seasonal changes in ground water table due to irrigation drawdown could manifest changes to redox conditions.

CONCLUSIONS

Strata underlying the Caldwell area include fluvio lacustrine beds of the Idaho Group, a thick sequence of fluvial gravel, an 800-thousand year-old basalt lava flow, and overlying eolian and lacustrine beds. A paleo Snake River, prior to eruption of the basalt lava flows, may have deposited the gravel in channels carved into the top surface of the Idaho Group sediments.

Local concentrations of radionuclides in ground water probably result from ground water passing through strata that contains elevated concentrations of uranium- or thorium-bearing minerals. The source and distribution of these minerals is unknown. They may have accumulated as clastic mineral fragments in a paleo fluvial system, or perhaps as secondary minerals that grew at redox boundaries such as in roll-front uranium deposits. The radioactive minerals may occur either in the Idaho Group or in the overlying Willow Creek gravel sequence. Samples in the study area with elevated levels of radionuclides were collected from wells that either passed through or terminated in the Willow creek gravels, which certainly highlights the need to critically evaluate this section.

Figure 8: Black Canyon dam on the Payette River above Emmett. This is the most likely source for ground water in the Willow Creek gravel sequence.

Most of the ground water in the Willow Creek gravels resides above the elevation of Boise River, so apparently did not come from the river. The other possible sources of water are natural precipitation, and downward percolation of irrigation water. The dry climate of this area (WRCC, 2003) indicates that most of the water probably came from agricultural irrigation. This component comes via the Black Canyon canal from Black Canyon Dam on the Payette River. The dam has a pool elevation of 2512 feet. Water flows from the South side of the dam in the Black Canyon Canal, is pumped about 100 vertical feet into the C-Line canal, and is then distributed throughout northeastern Canyon County northeast of the Boise River. The water from this canal system that reaches the aquifer can only be only as old as the dam. Black Canyon Dam was built between 1922 and 1924.

RECOMMENDATIONS

Analyses from well-water samples will show conclusively the planimetric distribution of radionuclides, which is very important information. They will probably not reveal the specific information needed to address the problem of which strata hosts the radionuclides. Additional sampling from existing wells will likely result in similar results because of poor well-construction; in no case can the source elevation of a water sample be precisely determined unless the sample is collected during well construction by trained personnel. A reliable alternative may be to conduct gamma logs of key wells. The gamma log instrumentation will provide precise down-hole locations of collected data, and will reveal all concentrations of gamma-ray-producing media. A comparison of the gamma logs with lithologic logs will address whether the uranium concentrations occur in the Idaho Group or in the overlying Willow Creek gravels, or otherwise.

I recommend a two-phase process to define the distribution of elevated radionuclides in three-dimensions. The first phase should be well-water-sampling, designed to define the planimetric distribution of radionuclides. It should be more closely spaced around areas with known concentrations, and then enough samples regionally to characterize the overall metallic signature.

The second phase should involve radiometric logging of wells in areas that have concentrated radionuclides. Once completed and analyzed these results would reveal the overall geochemical system in which the radiation occurs, and that is what is needed to implement a successful solution to the problem.

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LIST OF FIGURES AND PLATES

APPENDIX 1: COMMONLY OCCURRING RADIOACTIVE MINERALS

(From http://www.sjgeophysics.com/table.html)

URANIUM MINERALS

URANIUM URANINITE (PITCHBLENDE)

Composition

Complex oxide of U, Pb, Ra, and other metals, including thorium and the rare earths Secondary uranium minerals such as gummite, carnotite, torberhite, autunite, tyuyamunite, etc., usually associated with it The most important uranium ore.

Color and habit

Black, massive mineral with greasy, or pitch like, luster; rarely in crystals

Mode of occurrence

Found in pegmatites and granites, and in veins with silver, lead, copper, etc. One of the largets deposits is at Great Bear Lake, Canada, where uraninite occurs with native silver and other minerals in veins, shear zones, folded sediments, and volcanics intruded by pre-Cambrian granite. In the Colorado Front Range, Gilpin County, Colo., Marysvale, Utah, and western Montana, gold-silver-quartz-pyrite veins carry uraninite. Important European vein deposits of uraninite are in Cornwall, England, Czechoslovakia, and Saxony, where veins carry silver. Greatest deposits in world are in Katanga Basin of Belgian Congo, where uraninite and its alteration product, gummite, occur in veins associated with copper deposits in faulted and crumpled limestones. Madagascar deposits are in pegmatites. Recent production from veins in Beaver Lodge area, Saskatchewan. Important new vein deposits in Cochetopa district, Colo.; western Montana; Australia. Important placer deposits in gold-bearing conglomerates at Blind River, Ontario. Recently found in sedimentary rocks in copper-uranium deposits of southern Utah, northern Arizona, and Australia; near LaSal, Utah; in sandstone and limestone in Laguna-Grants area, N. Mex.

DAVIDITE

Composition

Rare earth-iron-titanium oxide; 7-10% U_3O_8

Color and habit

Angular, irregular masses; brown to black; glossy to submetallic luster

Mode of occurrence

Became significant in 1951 when found at Radium Hill, Australia, occurs in gneisses and veins with ilmenite.

Gummite

Composition

Doubtful

Color and habit

Yellow to brown, massive or in rounded or flattened pieces with greasy luster

Mode of occurrence

Alteration product of uraninite and commonly associated with it. Abundant at Katanga, Belgian Congo, and in Mitchell County, N.C.

Carnotite

Composition

Approximately $K_2O \cdot 2UO_3 \cdot V_2O_5 \cdot 2H_2O$

Color and habit

Secondary mineral. Yellow crystalline powder or earth masses found in sandstones; often associated with fossil logs or bones and other secondary minerals

Mode of occurrence

Found and mined in large quantities in southwestern Colorado, Utah, and New Mexico, where ore is major source of uranium in the United States. Important new deposits in Black Hills, S. Dak., in Wyoming and Ferghana Basin, U.S.S.R. Also obtained from South Australia, Katanga, Belgian Congo, and Pennsylvania. Carnotite and uraninite are chief ores of uranium.

Torbernite

Composition

$Cu(UO_2)_2)P_2O_8 \cdot 12H_2O$

Color and habit

Secondary mineral. Emerald green; square tabular crystals or micaceous aggregates

Mode of occurrence

Occurs associated with autunite and other uranium minerals, with uranite in Belgian Congo and Czechoslovakia; occurs in North and South Australia, Cornwall, England; with tyuyamunite in Turkestan, U.S.S.R. Also in the copper-uranium deposits of Utah and Arizona.

Autunite

Composition

$Ca(UO_2)_2As_2O_8 \cdot 8H_2O$

Color and habit

Secondary mineral. Sulfur yellow; square tabular crystals or micaceous aggregates

Mode of occurrence

Associated with other uranium minerals in Czechoslovakia, Turkestan, South Africa, northern Portugal, Cornwall, and South Australia. In the United States occurs sparingly in pegmatite in Connecticut; at Philadelphia; in mica mines of Mitchell County, N.C.; Black Hills, S. Dak.; Utah; and New Mexico. Important new deposits associated with uranophane, carnotite in Karnes City, Tex., in sedimentary rocks. On Spokane Indian Reservation, Wash., at contact of intrusives and argillite.

TYUYAMUNITE

Composition

$CaO \cdot 2UO_3 \cdot K_2O_5 \cdot H_2O$

Color and habit

Similar to carnotite but with slightly more greenish color

Mode of occurrence

Ore in southeastern Turkestan, U.S.S.R., and important constituent at Laguna-Grants, N. Mex.

URANOPHANE

Composition

$CaO \cdot 2UO_3 \cdot 2SiO_2 \cdot 6H_2O$

Color and habit

Slightly lighter color than autunite

Mode of occurrence

Association similar to autunite and torbernite. An ore mineral at Grants, N. Mex. Important in sandstone in Wyoming. Common noncommercial mineral in granites and pegmatites in Georgia and New Hampshire.

Uranium, columbium, and rare earths Euxenite, samarskite, brannerite, betafite, pyrochlore, fergusonite, etc.

Primary oxides of Ca or Na and varying amounts of uranium, thorium, titanium, columbium, tantalum, and the rare earths All are black to yellow brown Occur along with other minerals typical of pegmatites, veins, contact metamorphic areas, and some placers. Brannerite is an ore at Blind River, Ontario, and Idaho placers. Pyrochlore and betafite at Hybla, Ontario, Oka, Quebec, and similar localities. Madagascar pegmatites are rich in fergusonite.

COLUMBITE-TANTALITE

Composition

Variable from (Fe, Mn)O•Cb_2O_5 to (Fe, Mn)O•Ta_2O_5; 0-0.6% U_3O_8

Color and habit

Black to reddish-brown crystals and masses

Mode of Occurrence

Principal columbium-tantalum minerals. In same associations as the above minerals. In Belgian Congo, Nigeria as ore. Often with beryl, as in Brazil.

THORIUM MINERALS

MONAZITE

Composition

(Ce, La, Di) PO_4 with small percentages of $ThSiO_4$, usually 3-9%

Color and habit

Small red, brown, reddish, or brownish crystals Accessory mineral in granites, gneisses, aplites, and pegmatites, but commercially valuable occurrences are mostly placer deposits.

Mode of occurrence

Placers in the Carolinas, Florida, and Idaho are mined; famous placer deposits of monazite occur in Brazil and Travancore, India, which until 1945 supplied two-fifths of the world's monazite. Important vein deposits found since 1950 in Idaho; in California with rare earths; and in South Africa, which is now a major source.

THORIANITE

Composition

ThO_2 with varying amounts of UO_2 and UO_3

Color and habit

Black to brownish gray; greasy luster; looks much like uraninite.

Mode of occurrence

In pegmatites, granites, etc., and placers. Became commercial source of thorium in 1955 from placers in Madagascar.

THORITE AND URANOTHORITE

Composition

$ThSiO_4$ with possible small percentages of uranium

Color and habit

Usually black, sometimes orange-yellow; square crystals

Mode of occurrence

In granites, pegmatites, etc., and placers. Has been found in pegmatites in Norway, Madagascar, Hybla, Ontario, North Carolina. Veins in Idaho and California. In placers in New Zealand, California.