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*An ugly hemorrhage
from the air
the Flows
like the oceans
or the greatest mountains
explains its integrity
to those who venture.*

*This archipelago
is like desire
in that you access the center
from any one of its entrances.*

- Will Peterson

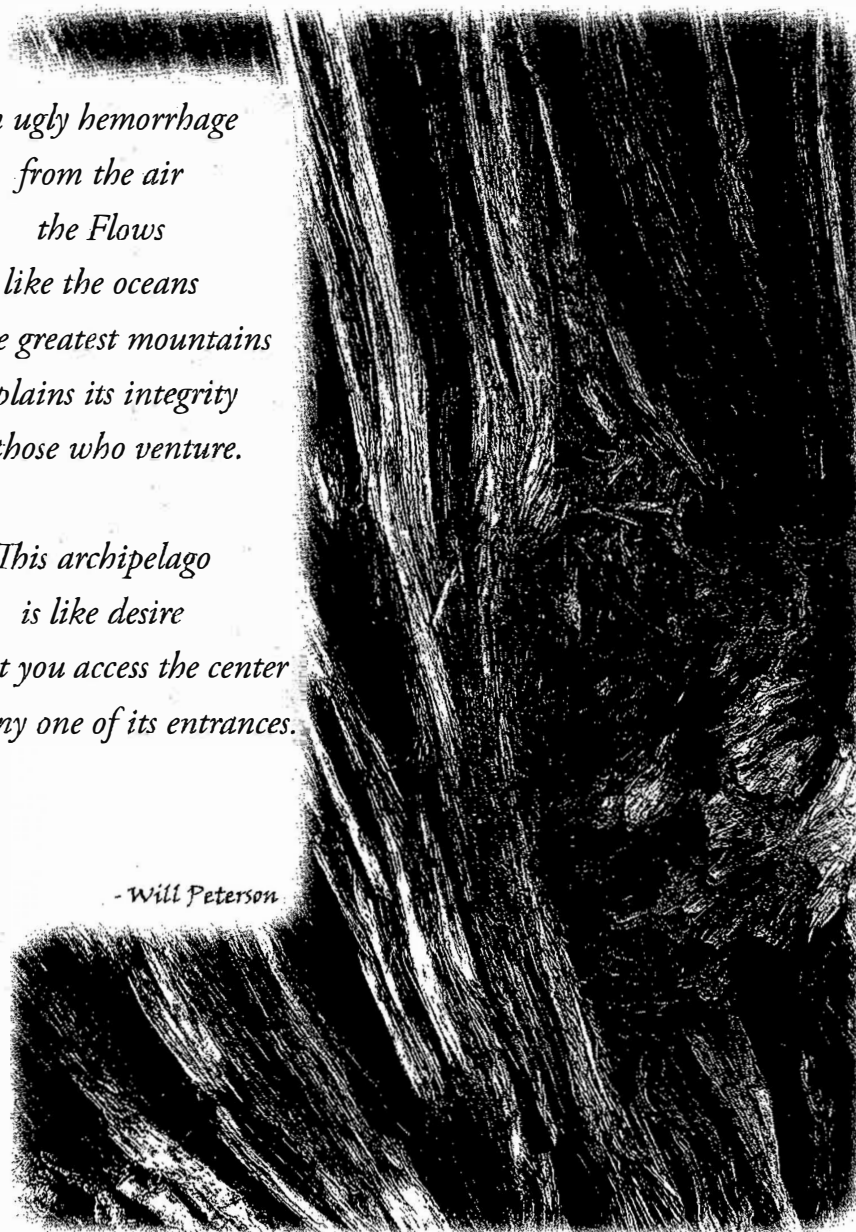


Photo by Roger Boe

Radioactivity at Hagerman Fossil Beds National Monument, Hagerman, Idaho

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ABSTRACT

The Idaho State Fossil, the "Hagerman Horse", is radioactive at 1,600 counts per minute. Naturally occurring radioactivity has been measured at Hagerman Fossil Beds National Monument, located in south-central Idaho, in both fossil and mineral deposits since 1996. New information from a sampling of over 300 fossils using a Geiger-Muller instrument indicates radioactive emission levels in some specimens near 7,000 counts per minute. About 45% of the 300 samples exhibited levels above 500 counts per minute. Mineral deposits have also exhibited above ambient background levels at about 130 counts per minute. Non-destructive analysis using X-ray fluorescence has shown the presence of uranium, iodine, strontium, yttrium and nearly all Lanthanide series or Rare Earth elements. The geologic association appears to be that fossils derived from coarse grained sediments are higher in radioactivity, than ones found in clay rich deposits, which are near ambient background levels. The authors suggest that ancient groundwater transported radioactive elements through sand bodies and cavernous basal sections of interbedded basalt flows which precipitated out of solution during the mineralization process. Field results indicate that a Geiger-Muller counter may be a viable tool in the search for and safety determination of fossils.

BACKGROUND

Hagerman Fossil Beds National Monument (HAFO), was commissioned in 1988 to preserve, protect, and provide for the study of the Pliocene fossil assemblage. The Idaho State Fossil, the "Hagerman Horse", was discovered at HAFO, located approximately 90 miles southeast of Boise. Over 1,000 fossil sites have been mapped with mostly terrestrial mammals represented from the floodplain environment of ancient Lake Idaho that deposited the Glens Ferry Formation (Malde and Powers, 1958). At least 111 radioactive fossil sites have been documented at HAFO, including the

"Hagerman Horse Site", but not all of the fossil sites have been tested for radioactivity.

EQUIPMENT

In 1996 high levels of radiation were detected in fossil specimens at HAFO using a Geiger-Muller (GM) instrument (Figure 1). The methods and equipment produce quasi-quantitative results for a surface emission rate but it is sufficient for a preliminary scoping-level investigation. The GM instrument detects primarily beta radiation and very small amounts of alpha and gamma. Readings from the meter are reported as gross counts per minute (cpm).

but the meter is only 33% efficient so the cpm value can be multiplied by a factor of three to obtain a value more representative of the actual emission rate. For example, a meter reading of 500 cpm x 3 equals 1,500 actual radioactive decays per minute. Further, the meter only detects emissions from the facing side of the specimen; the meter will not detect the emission from opposite side of the specimen. Therefore, the 1,500 value would need to be approximately doubled to 3,000 to more accurately reflect the total radioactive emission. Future investigations should use a counting chamber to obtain accurate, precise and total radiation emissions. A cursory analysis was



Figure 1. Hagerman Horse mandible fossil tested with a Geiger-Muller instrument.

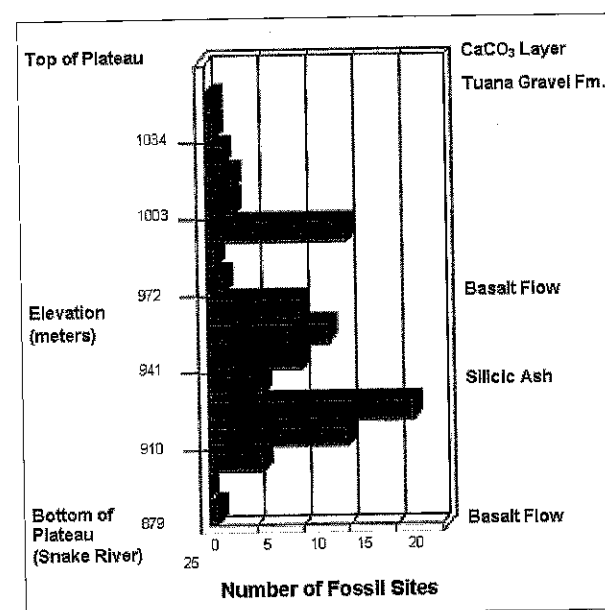


Figure 2. Vertical frequency graph showing 111 radioactive fossil sites (x axis) at HAFO relative to elevations (y axis in meters).

performed at the University of Idaho which identified uranium in measurable quantities up to several percent concentrations (Farmer and Knowles, 1996) and mining claims were filed in the 1950's within the Monument area for these radioactive deposits.

RADIOACTIVITY

During 2005, over 300 fossil specimens were tested with a Geiger-Muller counter TBM-3S manufactured by "Technical Associates" (Figure 1). One hundred thirty six fossils (45%) exhibit levels of 500 cpm or higher, one specimen (cat. # 256) responded at 7,000 cpm. Only one value was selected and included in the testing from the "Horse Quarry Site" to avoid bias in the data due to the high number of radioactive fossils from this one site. Seventy-five percent of the samples tested responded with measurements at twice the ambient background (20-50 cpm) or higher. The meter was checked before and after each sample for ambient background levels. A detailed chemical analysis (Data Chem, 1997) was performed on a fossil specimen that identified the following isotopes; uranium²³⁵ & ²³⁸, lead ²¹⁰ & ²¹⁴, bismuth²¹⁴, radium²²³ & ²²⁶, protactinium²³¹, and cesium¹³⁷. The chemical analysis correlates to the radioactive character of the fossil specimens during this investigation.

GEOLOGIC ASSOCIATION

A preliminary scoping study, to determine presence, absence and spatial distribution of radioactivity, revealed that most of the radioactive fossils are found in ancient river channels filled with porous fine to coarse grained sand. Generally, the presence and level of radioactivity dissipates in the upper and basal levels of stratigraphy of the plateau by about 30 meters (100 feet). The presence and levels of radioactivity increase in fossils deposited in sand units and decrease in fossils found in clay rich deposits. Porosity appears to play a role in the hypothetical transport of dissolved uranium flowing within ancient groundwater systems through porous geologic deposits.

The original source for the uranium is unknown but it is likely incorporated into the fossil mineral lattice structure through a process of chelation. Dentitions appear to have higher concentrations than other parts of the fossil. The presence of radioactivity appears to dissipate in the upper elevations (Tuana Gravel Formation) based on testing a camel fossil, pine species log, and a CaCO₃ layer. It also decreases in the lower elevations of the stratigraphy based on testing an unnamed basalt base at an elevation of 869 meters and minor numbers of fossils. The Shoestring basalt (Malde, 1962) base, located at an elevation of 975 meters, exhibits post-eruption secondary mineralization with FeO₂. Uranium was probably incorporated into

this mineralization process from groundwater under the same conditions as the fossils.

SURVEY DATA

Elevations of fossil sites were derived from two different methods. Older surveys used a "Criterion" laser transit tied into benchmarks placed by the U.S. Bureau of Land Management Cadastral division in 1993 to calculate coordinates to an elevation accuracy of 0.3 meter (1 foot). The second method used a combination of horizontal coordinates from a Trimble Pro XR with corrected data to produce horizontal accuracy of about 1 meter. These points were plotted in ArcGIS 8 with five-foot contour line intervals that have a vertical

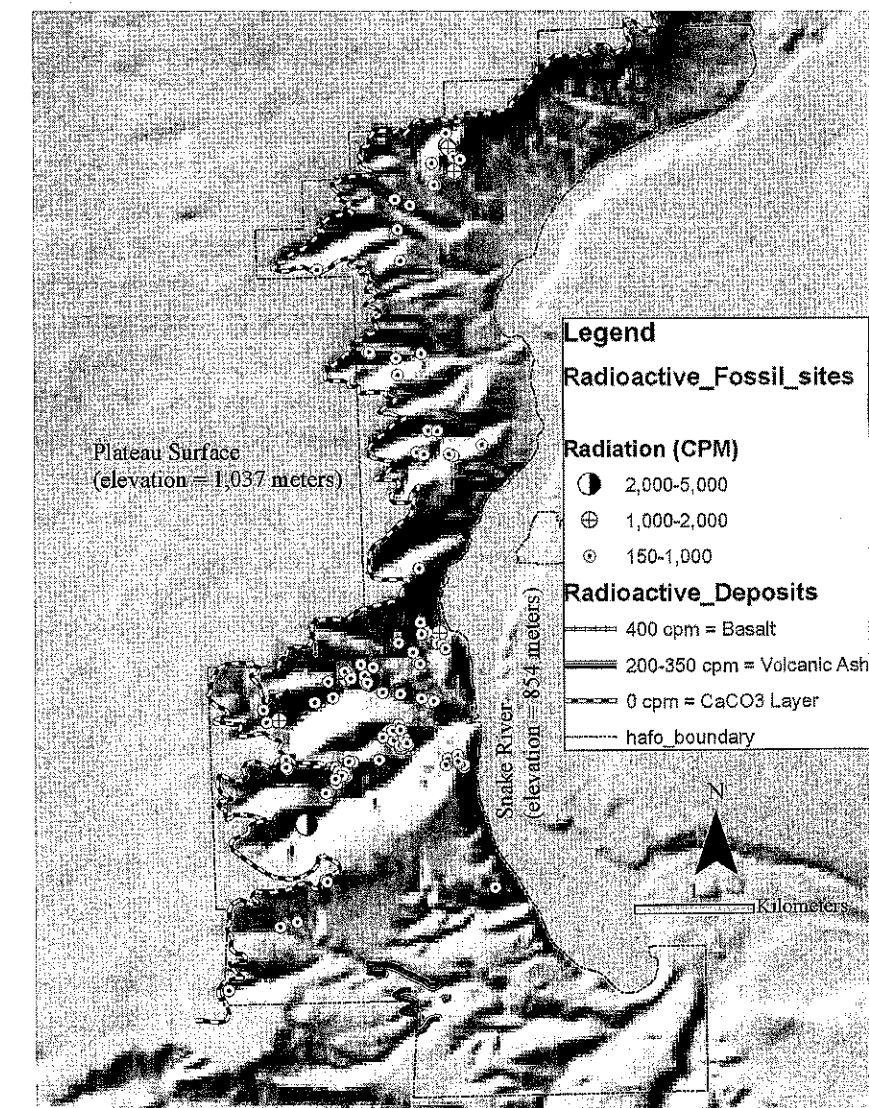


Figure 3. General location map showing horizontal distribution patterns of radioactive fossil sites.

accuracy of 0.10 meter. Fossil site elevations were interpolated based on these contour lines and GPS derived points thereby eliminating the use of GPS elevations which are notoriously inaccurate. Then all of the sites were grouped into 10 meter elevation zone categories shown in Figure 2 as the horizontal bar graphs.

MAPPING

A preliminary map (Figure 3) and vertical frequency distribution graph (Figure 2) were developed using GIS to aid this scoping investigation and park management with identifying the vertical and horizontal distribution of radioactivity. The circles denote radioactive fossil sites with different levels of radioactivity in cpm. The lack of sites in the northern and southern 25% of the Monument is due to less fossil exposure from erosion, more vegetation and ancient landslides. The sinuous dashed line on the left side of Figure 3 is a CaCO_3 layer that exhibits only ambient background levels of radioactivity. The CaCO_3 layer is located at the top of the formation at an elevation of 1,036 meters (3,400 feet). The black lines in the south area represent the Peter's Gulch silicic volcanic ash which tested at 70 to 120 cpm. In the north area is the Shoestring basalt flow positioned at an elevation of 975 meters (3,200 feet), mid-level within the geologic section, noted with a black hachured line. The rubble iron oxide base



Figure 4. Iron oxide rubble base of the mid-section basalt flow tested at 400 dpm.

(Figure 4) tested at 400 cpm while the massive part of the basalt above the rubble base is near ambient background levels.

The base of the lower unnamed basalt at an elevation of 869 meters (2,850 feet) also tested at ambient background levels and it is located at a low elevation in the formation. The vertical distribution (Figure 2) indicates most of the radioactive sites are located approximately between 900 (2,953 feet) and 1,000 meters (3,281 feet) elevation. The elevation of the Snake River is 854 meters (2,800 feet) and the top of the plateau is about 1,052 meters (3,450 feet). It is unknown why radioactive deposition appears to be concentrated between these elevations.

HUMAN HEALTH HAZARDS

Human health concerns have resulted from the presence of radioactivity. Exposure occurs from handling of specimens during preparation and inhalation of radon and its decay daughter products. Radon gas, a byproduct of uranium decay, has been documented inside fossil storage cabinets with a maximum of 544 and average of 436 pico-Curies per liter (pCi/L) noted in Figure 5 (McBride, 1996). Ambient radon gas concentrations in the fossil storage room have been recorded by National Park Service staff with a maximum typical value of 24 pCi/L. The U.S. Environmental Protection Agency recommends homes with radon gas concentrations of 4.0 pCi/L take action to reduce levels. The National Park Service is deficient implementing corrective protective actions as of 2006 (NPS, 2004); ten years after the initial radon tests documenting high concentrations.

In 2001, HAFO continued to allow children to handle radioactive fossils (Figure 6) at the "Hagerman Horse Quarry Site" during its "Camp Pliocene" summer programs (HAFO, 2001). There are benefits from the radioactive deposits such as using the presence, absence or level of radioactivity as a tracer to assist with mapping the distribution of geologic deposits and fossils on the Monument.

Usage of a Geiger-Muller counter during

field work assisted Monument staff with the discovery of a recent Mastodon fossil tusk which was determined to be radioactive at 350 cpm. There is potential to use the radioactivity as a tracer to determine ancient sediment source areas and age dating.

CONCLUSIONS

Naturally occurring radioactivity is well documented at Hagerman Fossil Beds National Monument at highly elevated concentrations. The official "Idaho State Fossil" site is radioactive at 1,600 cpm. It is unknown why the spatial distribution of radioactive fossil sites occurs primarily between an elevation zone of 900 to 1,000 meters. They are most commonly found associated with ancient river channels filled with sand and fossils found in clay rich deposits do not exhibit discernable levels of radioactivity. Similarly, the basalt low in elevation exhibits ambient background levels while the upper basalt has higher levels. Radon is documented in fossil storage collection facilities at highly elevated concentrations up to 544 pCi/L. About 45% of 300 fossils tested with a Geiger-Muller instrument resulted in responses of 500 counts per minute or higher and 75% exhibited radioactivity at twice the ambient background or higher. Further detailed investigations are ongoing at this time.

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HONEYWELL

Professional
Radon Monitor

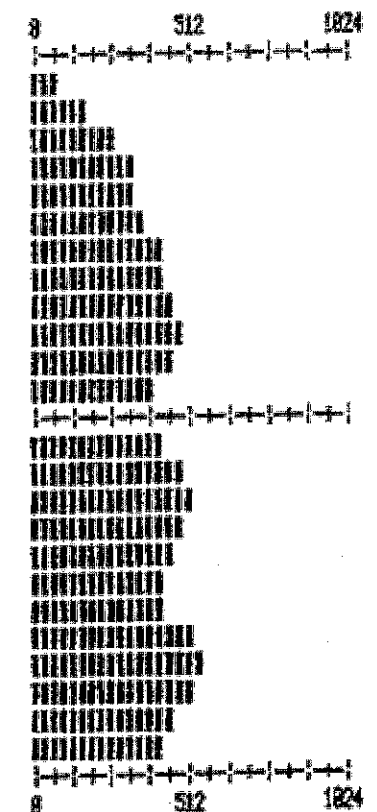
Start Date 7-8-96
Start Time 11:47 AM
Serial #
Location Cabernale

Signature: [Signature]

Data in pCi/l
Time Interval 4 Hrs

64.0	184	272
324	348	376
432	428	456
484	456	488
428	488	516
496	468	436
444	520	544
512	464	440

Overall Avg.=436
Last 12 Hrs.=462



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Figure 5. Radon concentration test inside fossil storage cabinet.

Bulletin, v. 73, no. 10, 1197-1220 p.
 McBride, J., 1996, unpublished radon test results located at Hagerman Fossil Beds National Monument, Idaho.
 National Park Service Final Environmental, Safety and Health Audit Program, Findings and Observations Report, June 21, 2004, Finding ID: HAFO-011, approximately 50 p.

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I would like to thank Bob Willhite, former Park Ranger, for his support of this project from 1996 through 2001. I would like to thank the manuscript reviewers and Hagerman Fossil Beds staff for testing fossils for radioactivity.

HAGERMAN FOSSIL BEDS NATIONAL MONUMENT

The FOSSIL RECORD

FALL 2001

VOLUME 10, No. 3

THE BARE BONES OF THIS ISSUE:

Winter Hours

Summer Recap

New Staff

Resource Management

Archaeology Corner

Camp Pliocene

Educational Opportunities

"Indeed, when I go to the woods or the fields, or ascend to the hilltop, I do not seem to be gazing upon beauty at all, but to be breathing it like the air."

John Burroughs, from *The Earth Speaks*

CAMP PLIOCENE 2001



Figure 6. Children handling the radioactive "Hagerman Horse" Idaho State fossils.



Keynote Speakers

Lava Super-eruptions; Environmental and Landscape Effects

Stephen Self

Volcano Dynamics Group, Dept. of Earth Sciences,
 The Open University, Milton Keynes, United Kingdom



How will the next volcanic super-eruption affect us? Stephen Self will begin by explaining how plains-type basaltic volcanism, defined from lava fields such as the Craters of the Moon and others in the western USA, occurs and changes the landscape. Drawing on information from similar historic events such as Laki (Iceland) in 1783-84 and Lanzerote (Canary Islands) in 1730-36, which both erupted approximately 10-15 cubic kilometers of magma, the formation of fissure vent systems (like the Great Rift), the output of lava from the vents, and the emplacement of the lava flow fields will be discussed. Magma degassing is an important aspect of such eruptions. The severity and style of atmospheric impact that may arise from volatile releases during a future plains-type eruption will be highlighted.

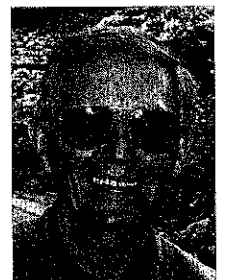
Self will then scale-up to lava super-eruptions, or the formation of flood basalt provinces, which have occurred sporadically throughout Earth history. These huge lava provinces have volumes ranging from 100s to millions of cubic kilometers, such as the Columbia River Basalt and Deccan (India) provinces. They were produced at extremely fast rates and are distinguished from all other basaltic volcanism by the repeated effusion of huge batches of magma. Self's studies of the Columbia River Basalt lava flows suggest that eruptions of this magnitude last in the order of a decade and are capable of emitting huge amounts of sulfur dioxide gas. The potential atmospheric impact of such large-scale, long-term events is being investigated, but even smaller ones, such as Laki, have had disastrous effects.

Stephen Self has studied volcanoes and volcanic rocks in almost every part of the world and has written over 140 articles in the scientific press and popular magazines. He has taught short courses for universities and industry, and has been a keynote speaker at international conferences. Self was previously a Professor in the Department of Geology and Geophysics at the University of Hawaii. He now holds the Chair in Volcanology at the Open University, UK, and heads the Volcano Dynamics Group in the Department of Earth Sciences. He is currently leader of the UK's Volcanic and Magmatic Studies Group and coauthor of the Geological Society's Working Group report on Super-eruptions. His research interests include large-scale basaltic volcanism, mechanisms and deposits of explosive volcanic eruptions, and the effects of eruptions on global climate and the environment.

Archaeology and Human History on Idaho's Snake River Plain

C. Melvin Aikens

Emeritus Professor, University of Oregon



People have lived on the Snake River Plain for perhaps 15,000 years, since the waning of the last ice age. Their cultures changed again and again over that time, always being shaped by the area's distinctive natural environment. Archaeological evidence, interpreted through the medium of Native American traditional knowledge, reveals the human story.

C. Melvin Aikens began his archaeological career in 1958 as an undergraduate field assistant on the Glen Canyon archaeological project in southeastern Utah. After several years work in the Southwest, he developed research interests in the broader intermontane western region, especially the Great Basin, which he continues to pursue. He served for a number of years as Head of the Department of Anthropology and currently serves as Director of the University of Oregon Museum of Natural History. He holds a B.A. degree in Anthropology from the University of