

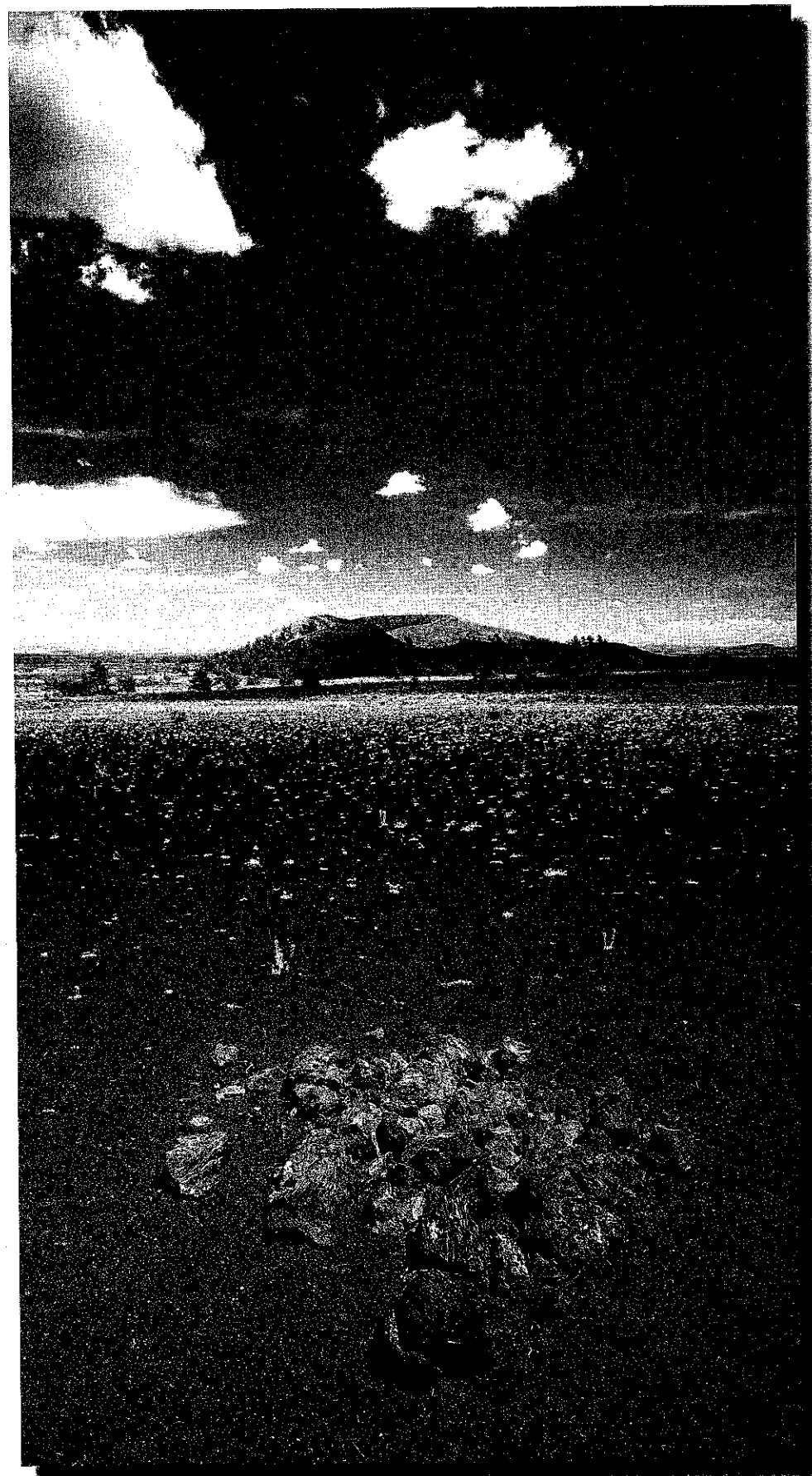


Photo by Tim Frazier

Paleochannels of the Big Lost River, Idaho

Catherine M. Helm-Clark

Department of Geosciences, Idaho State University, Stop 8072, Pocatello, ID 83209

Paul K. Link

Department of Geosciences, Idaho State University, Stop 8072, Pocatello, ID 83209

ABSTRACT

The detrital zircon age spectrum of the Big Lost River is absent in 4 Ma beds of the Pliocene Glens Ferry Formation at Hagerman Fossil Beds National Monument. Based on stratigraphic data south and west of the Great Rift of Idaho, undated gravel-bearing sediments represent possible paleochannels of the ancestral Big Lost River flowing south and west, into playa sinks represented by multiple subsurface clay layers between the Wapi basalt flow and Dietrich Butte. An ancestor of the Pleistocene-to-Holocene Great Rift erupted across these paleochannels, and the Big Lost River was forced to flow north and east into the Big Lost Trough south of the Lemhi Range. After 2 Ma and likely earlier, Big Lost River sediments were deposited in the Big Lost Trough.

INTRODUCTION

Previous research has shown that the Big Lost River was captured within the Big Lost Trough between 2.5 Ma, and 1.8 Ma (Geslin et al., 2002; Bestland et al., 2002; Blair, 2002). The river diversion to the northeast is attributed to the rise of the Axial Volcanic High, a low-relief ridge formed by small low-angle shield volcanoes (figure 1). These conclusions depend on sediment provenance studies using grain-size and detrital zircon analyses and on paleomagnetic correlations and K-Ar and Ar-Ar radiometric age dating.

A recent $^{40}\text{Ar}/^{39}\text{Ar}$ age date of basalts above delta-margin lacustrine sediments at 422 m (1385 ft) in INL drillhole C1A (Helm-Clark and Rodgers, 2004) suggests that they belong to the Jaramillo Paleomagnetic Subchron of 0.99 to 1.05 Ma instead of the ~2 Ma Olduvai subchron as previously suggested (Champion et al., 1988; Anderson et al., 1997; Blair, 2002). The inference is that the Olduvai sequence is missing at this location or is substantially deeper

than originally interpreted (Helm-Clark et al., 2005), which in turn suggests southwestward Pleistocene tilting or differential subsidence within the Big Lost Trough.

METHODS

Data discussed here include geomorphology of regional volcanic rifts zones, stratigraphy from well logs, and provenance information from detrital zircon age spectra, as applied to paleodrainage patterns on the eastern Snake River Plain.

Stratigraphic information was reviewed using well logs from the Idaho National Laboratory and the water-well database of the State of Idaho Department of Water Resources. Well logs from the Idaho National Laboratory cover the Big Lost Trough and its environs in detail. Outside of the Big Lost Trough neighborhood, only drillers' logs in the Idaho database are available. Log quality is variable but most logs contain useable though simplistic stratigraphic information. The database

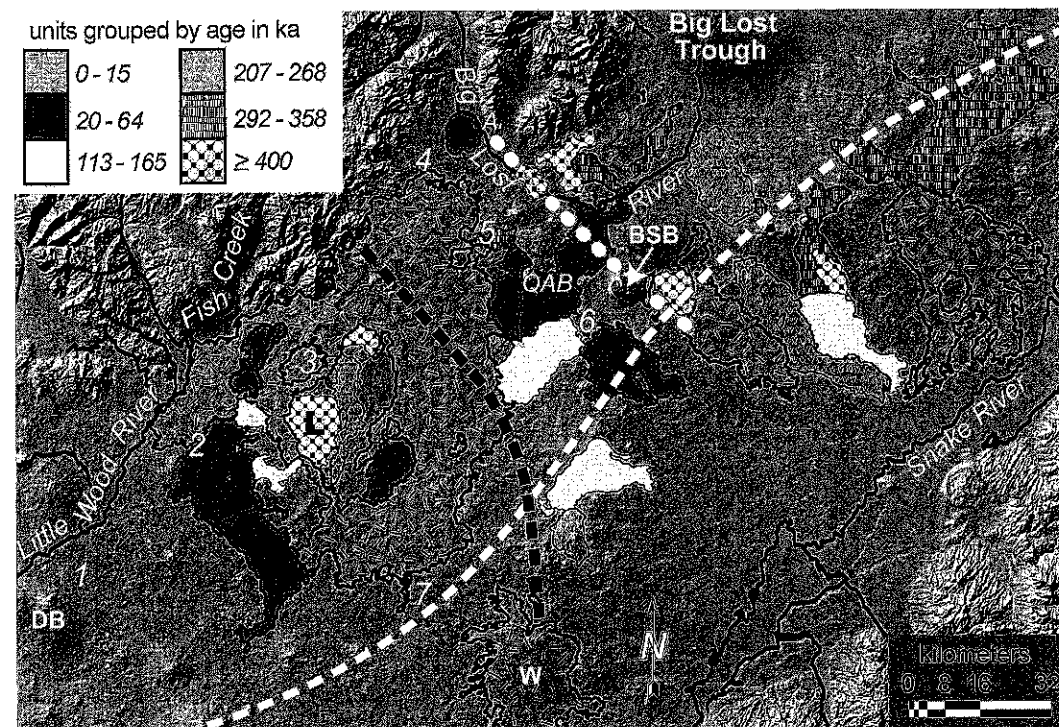


Figure 1. Dated volcanic rock units near the Great Rift of Idaho. Unit boundaries are based on LaPoint (1977), Kuntz et al. (1988), Kuntz et al. (1994) and Helm-Clark (unpublished data, 2002-2005). Major stream and river drainages are labeled. The white dashed line is the trend of the Axial Volcanic High. The black dashed line is the general trend of the Great Rift. The white dotted line is the general trend of the Arco Rift. The Big Lost River currently flows south out of a intermountain valley at Arco (white A, top center). It is blocked from flowing south or west by the elevated volcanic centers at the northern end of the Great Rift and the cluster of shield volcanoes around Quaking Aspen Butte (white QAB, center of figure). It instead turns east upon entering the Eastern Snake River Plain, incising a canyon through basalt across the Arco Rift, and finally flows to the northeast toward its sink in the Big Lost Trough (top center). Southwest of the Great Rift and north of the Axial Volcanic High, a second ridge feature trends northeast to southwest. The most prominent peak on this ridge is Laidlaw Butte (black L, center left). The area with interbedded clays in basalt extends from the Wapi Flow (black W, bottom center) to Dietrich Butte (white DB, bottom left). Numbers in white mark the locations of the seven wells whose stratigraphy is shown in figure 4.

was examined for 97 township-range blocks covering an area of ~9000 km² bounded by the Pioneer Mountains in the north, the Little Wood River in the west, the Axial Volcanic High in the south and Rt. 26 in the east. This area is mostly unpopulated and much of it belongs to Craters of the Moon National Monument. Well logs are not abundant in the study area and usually record only basalt; however, twenty-nine well logs did described interbedded sediments.

U-Pb ages were determined for zircon grains in river sands from the Big Lost and Big and Little Wood Rivers using the SHRIMP (Sensitive High Resolution Ion Microprobe) at Australian National University, employing standard detrital zircon techniques (Williams,

1998; Link et al., 2005). Each analysis consisted of 4 scans through the mass range. The data were reduced as described by Williams (1998, and references therein), using the SQUID Excel Macro of Ludwig (2000). Each detrital-zircon sample contains ~60 zircon grains sampled randomly from a mineral-separate.

Detrital-zircon age populations for stream sand within the Snake River system distinguish its provenance (Geslin et al., 1999, 2002; Link et al., 2002, 2005). During the northeastward migration of the Continental Divide and subsidence of the Snake River Plain since 15 Ma, there have been several instances of stream capture and drainage reversal related to lava-flow dams and Snake River Plain subsidence

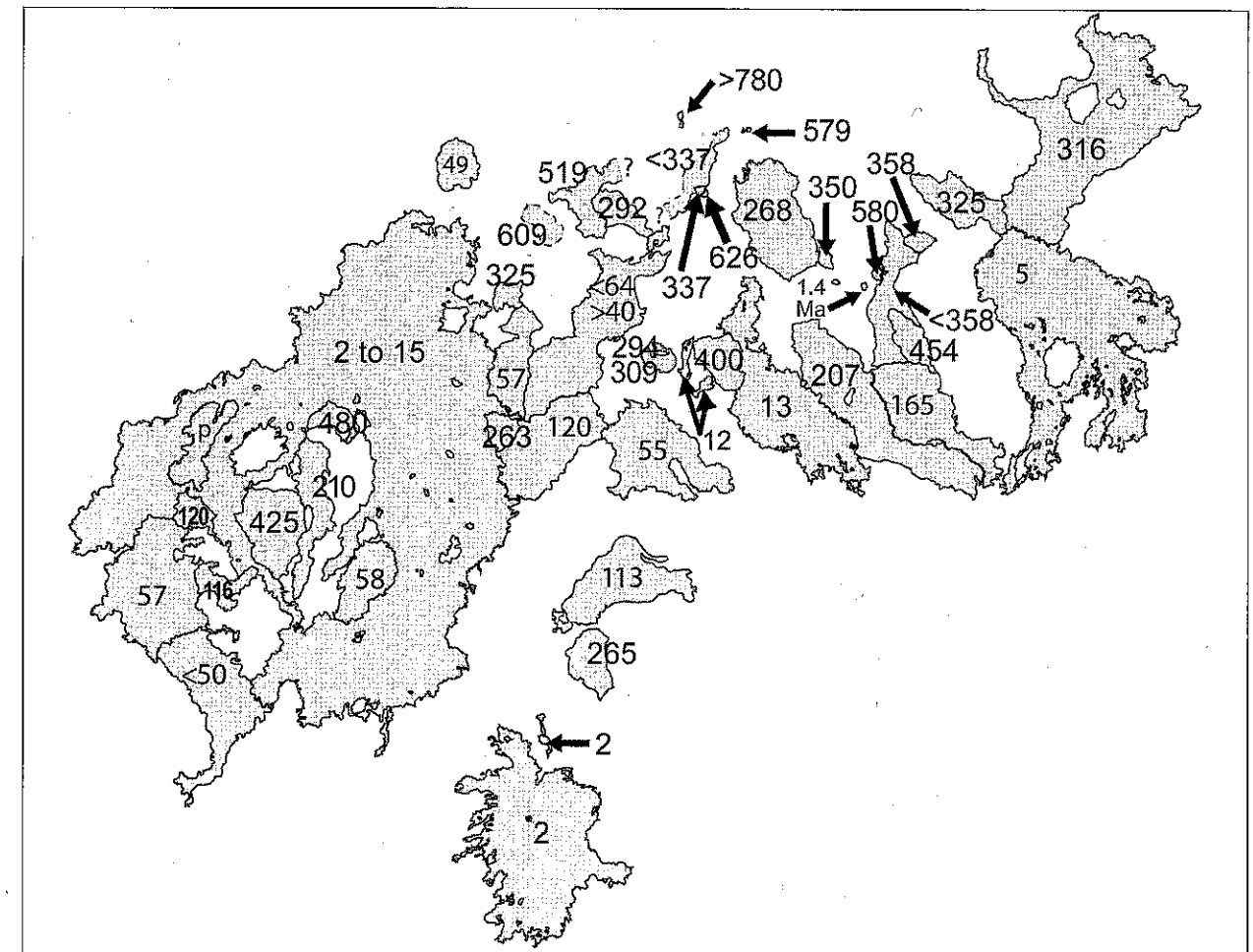


Figure 2. Volcanic units with individual ages in thousands of years (ka, kilo anno) unless otherwise noted. Basalts at Paddleford flat (labeled "p," center left) are estimated as between 20,000 and 40,000 years old. Standard errors on age dates are listed in Table 1.

(Pierce and Morgan, 1992; Beranek et al., 2006).

For data in this paper, Big Lost River samples include the river bed near Chilly, Idaho; Antelope Creek near its mouth; the Big Lost River at the Highway 26 Rest Area; and Big Lost River Pleistocene and Holocene sands 2 miles upstream from Highway 26. Wood River samples include Trail Creek above Corral Creek, the Big Wood River south of Bellevue, and the Little Wood River south of Carey. These data and sample locations are presented in detail in Link et al. (2005).

RESULTS

Active volcanic rifts on the Eastern Snake River Plain are characterized by Holocene and latest Pleistocene lava flows, lines of vents and fissures, and relatively elevated topography

(Wood et al., 2007; Helm-Clark, this volume). Figures 1 and 2, and Table 1, catalog the distribution of dated flows on either side of the NNW-striking Great Rift. Working backwards in time, westward water flow of the Big Lost River has been blocked by 2 to 15 ka lava flows erupted from the northern Great Rift at Craters of the Moon National Monument. Starting approximately at 40 ka, flow to the south and southwest was blocked by a elongate cluster of latest Pleistocene and older shield volcanoes in a topographic swell centered on Quaking Aspen Butte (QAB on figures 1 and 3) which is hypothesized to be a volcanic rift zone distinct from the Arco Rift (Helm-Clark, this volume).

Based on young volcanism at the North and South Robbers and Cerro Grande flows plus abundant Quaternary fissures and faulting, the Arco Rift is an active volcanic rift zone running

Table 1. Dated Volcanic Rocks on the Eastern Snake River Plain

Location	Age	Reference	Comments
Blue Dragon Flow	2076±45 yrs	K04	Youngest COM date
Kings Bowl Flow	2222±100 yrs	K88	
Wapi Flow	2270±50 yrs	K88	
Hells Half Acre Flow	5,200±150 yrs	K89	
North and South Robbers Flows	11,980±300 yrs	K94	
Cerro Grande Flow	13,380±350 yrs	K94	
Kimama Flow	15100±160 yrs	K04	Oldest COM date
Arco (Lost River) Flow	49 ka	S&F	
Wildhorse Butte	<50 ka	K04	⁴⁰ Ar/ ³⁹ Ar date; 10 km south of "the Blow Out"
Rock Corral Butte	55±12 ka	K04	
Broken Top lava field	57±30 ka	K04	Spud and Sand Buttes have similar paleomagnetic remanence directions as Broken Top and are probably the same age.
Fingers Butte	57±20 ka	K04	
Bear Den Butte	58±10 ka	K04	
Quaking Aspen Butte	>40 ka, <64 ka	K94, K04	Coyote Butte is overlain by Quaking Aspen Butte basalt
Coyote Butte	64±20 ka	K04	
Split Top Butte	113±10 ka	K04	
"The Blow Out"	116±15 ka	K04	
Serviceberry Butte	120±12 ka	K04	
Wagon Butte	120±25 ka	K04	
Taber Butte	165±22 ka	K94	
Table Legs Butte	207±65 ka	K94	
Big Blowout Butte	210±15 ka	K04	N of Laidlaw Butte
Pratt Butte	263±20 ka	K04	
Mosby Butte	265±30 ka	K04	
Mid Butte	268±32 ka	DC88	Lat 42.51N, Lon 247.23E,
Unnamed flow	292±58 ka	L94	"...collected along Rte. 20/26, 6.15 miles east of the junction of the road to Howe."
Big Southern Butte	294±15 ka	K94	NW side of top of butte, aphyric rhyolite cap of dome
Big Southern Butte	309±10 ka	K94	SE side of top of butte, flow-banded rhyolite core of dome
Kettle Butte	316±75 ka	K94	
Unnamed butte	325±45 ka	K94	Immediately west of Kettle Butte
Wildhorse Butte	325±10 ka	K04	North of Fingers Butte
Unnamed flow	<337 ka		Under 292 ka flow, above 337 ka vent west of AEC Butte
Unnamed vent	337±41 ka	L94	"...half a mile northwest of the top of AEC Butte."
Unnamed vent	350±40 ka	K94	Vent in kipuka immediately north of Middle Butte
Basalt vent on east side of East Butte	<358 ka		Immediately above basalt from vent at Radio Facility
Vent at Radio Facility	358±46 ka	K94	Northeast of East Butte
Cedar Butte	400±19 ka	K94	
Laidlaw Butte	425±25 ka	K04	
Unnamed vent	454±28 ka	K94	Immediately north of Taber Butte flow
Snowdrift Crater	480±50 ka	K04	
Crater Butte	519±52 ka	K94, L94	"...collected about 150 ft east of the Howe junction, very close to the northwestern edge of the Crater Peak flow."
State Butte	579±130 ka	K94	
East Butte	580±90 ka	K94	In rhyolite
Box Canyon	609±92 ka	K94	
AEC Butte	626±67 ka	DC88	
Unnamed rhyolite outcrop	1400±28 ka	K94	Between East and Middle Buttes

Reference key:

DC88 = Champion et al. (1988)

K88 = Kuntz et al. (1988), USGS Map I-1632

K89 = Kuntz et al. (1989)

K94 = Kuntz et al. (1994), USGS Map I-2330

K04 = Kuntz et al. (2004), OFR 2004-1222

L94 = Lanphere, M., USGS memo to Mel Kuntz and Steve Anderson, December 8, 1994.

S&F = Smith and Foeman, unpubl. data

USGS = United States Geological Survey

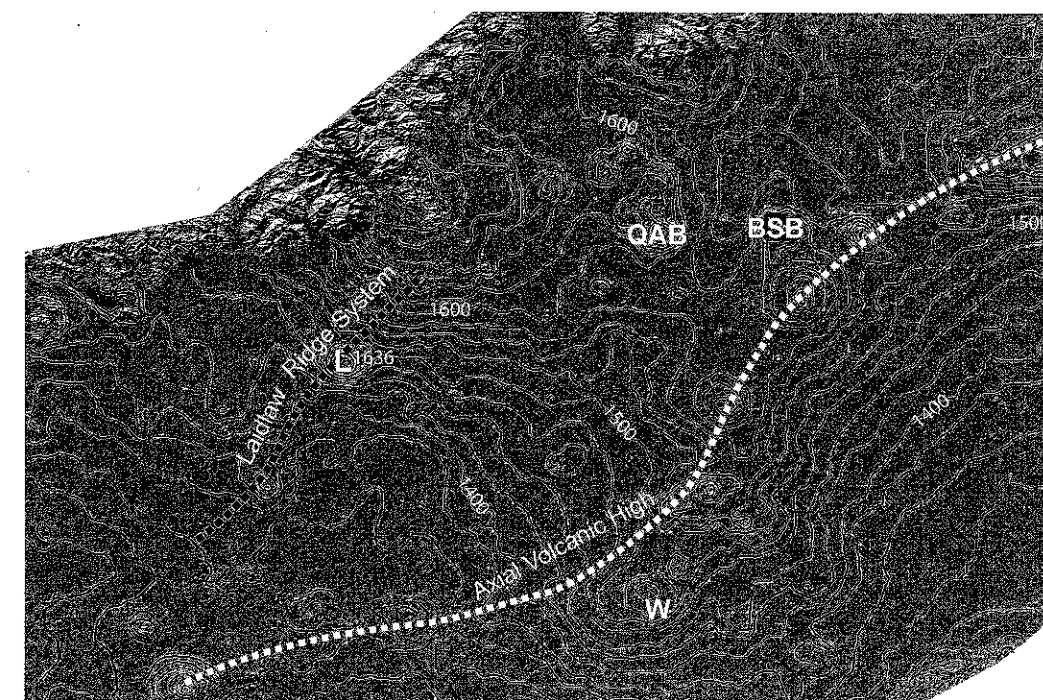


Figure 3. Topographic contours superimposed on a shade relief map of the study area. Contours were constructed using nearest neighbor analysis of USGS digital elevation data (DEM). Contour interval is 25 m. Notations are as follows: BSB = Big Southern Butte, L = Laidlaw Butte, QAB = Quaking Aspen Butte, W = Wapi flow vent at Pillar Butte.

from Arco through Big Southern Butte (BSB on figure 1). It is topographically elevated with respect to its surroundings and yet it does not block the Big Lost River from flowing to the east.

It is lower in elevation, however, than the swell centered on Quaking Aspen Butte to the south and the Great Rift to the southwest. The river crosses this rift as it down-cuts a channel into 519 and 609 ka basalts. Once across the Arco Rift, eastward or southward water flow is prevented by the Axial Volcanic High.

The Axial Volcanic High has been the loci for numerous eruptions (figures 1 and 2). The oldest known date of a surface rock associated with this feature is 1.4 Ma on a rhyolite exposed between East and Middle Buttes (upper right, figure 2). Surface water in the Big Lost Trough is blocked from flowing south by the Axial Volcanic High. Sedimentary data suggests that since sediments have been trapped in the Big Lost Trough for >2.0 Ma, the Axial Volcanic High has been a persistent feature on the Eastern Snake River Plain for

at least as long (Bestland et al., 2002; Blair, 2002). South of the Arco Rift, surface water is blocked from flowing south or west by the swell centered on Quaking Aspen Butte, by the north end of the Great Rift, and by a low ridge system between the mountains to the north and the Axial Volcanic High which we will call the Laidlaw Ridge System for convenience (figure 3). This ridge is at least a half a million years old since its two highest buttes, Laidlaw and Snowdrift Crater, are dated at 425 and 480 ka respectively.

The ~0.5 Ma basalts along Laidlaw Ridge immediately southwest of the northern Great Rift and the ~0.5 Ma basalts flooring the Arco Rift are in same elevation range; the topographic barriers of the Quaking Aspen Butte swell and the northern Great Rift are sandwiched between these two features. Here the greater relief is provided by the Great Rift and Quaking Aspen Butte swell, and not by the Axial Volcanic High, so it is the former two elevated features that prevent surface waters from flowing south to the Snake River.

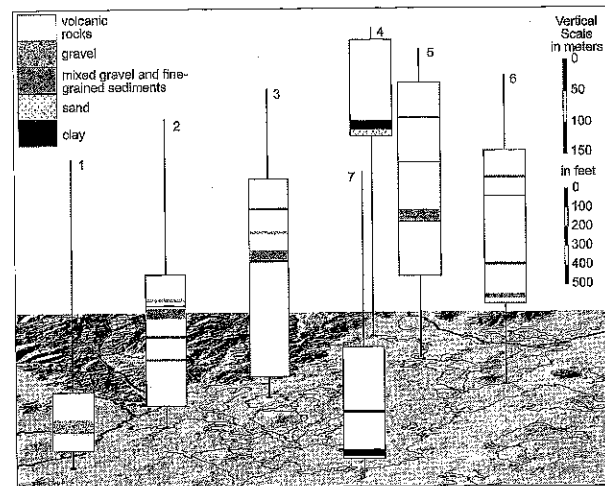


Figure 4. Stratigraphic diagram of representative lithological logs south and west of the modern drainage of the Big Lost River. Well information is listed in Table 2. The vertical line through each stratigraphic column is 488 m long (1600 ft) with a top elevation of 1676 m (5500 ft) MSL.

STRATIGRAPHY

Figure 4 shows seven representative stratigraphic columns for wells in the study area. Details of these wells are listed in Table 2. Our working assumption has been that gravels are only deposited by bed-load transport in rivers at flood (Graf, 1971). Based on this, the columns for wells 2, 3, 4, 5 and 6 show that streams which were likely the paleo-Big Lost River have flowed both to the southeast and to the southwest. The mixed gravel layer in well 6 is at ~235 m depth at a location south of both Big Southern and Quaking Aspen Buttes. The clay and sand units at depth in well 4 show that the river has deposited sediments also to the west, over 15 km from its current channel.

The mixed gravel unit in wells 5, 3 and 2 is similar to modern sediments observed today in the channel of the Big Lost River along its flood plain in the Big Lost Trough (Blair, 2002). This unit is at a slightly lower elevation in well 3 than in well 5. It is 50 m deeper in well 2. Wells 3 and 5 are on opposite sides of the Great Rift but are approximately equidistant from it. The northern Great Rift is uplifted with respect to the rest of the plain so it is not unexpected that the mixed gravel unit is higher in elevation in the wells closer to the rift than in the well

at a distance in a quiescent volcanic tableland. While it is possible that the mixed gravel layer in well 2 has its origin in the Little Wood River or Fish Creek, both wells 3 and 5 are north and east of where these streams enter the plain (Figure 1), thus placing a potential fossil Big Lost River channel underneath Craters of the Moon.

The shallow gravels in well 1 are likely from the Little Wood River. This location marks the western edge for the stratigraphic survey. To the east of well 1 is an area where two to three clay layers are interbedded with basalts between elevations of 1220 to 1310 m MSL. This area occurs in townships 5S and 6S and ranges 21E to 28E, between Dietrich butte and the Wapi Flow (Figure 1) making a elongate east-west strip just north of the Axial Volcanic High. The clay layers in well 7 are representative of this stratigraphy of interbedded clay layers in basalt.

DETRITAL ZIRCON

In figure 5, we compare the ages of detrital zircons in the Big Lost River system (five samples) with those in the Big Wood River system (three samples). For clarity, we show grains of age 0 to 150 Ma and grains 150 to 3500 Ma in separate plots. The data show the presence of 70 to 100 Ma grains in the Wood River system and their absence in the Big Lost River system. The reason for this difference is the presence of the Cretaceous Idaho batholith only in areas drained by the Wood River. Also, the Big Lost River system has a large component of 52 to 45 Ma Challis magmatic grains and a well-defined population of Neoproterozoic grains (600 to 750 Ma). This population is smaller and more diffuse in the Wood River samples. These respective patterns distinguish the two provenance areas from other drainages and from one another.

DISCUSSION AND CONCLUSION

Link et al. (2002) used the detrital-zircon data included here to demonstrate that the Wood River system was the primary sediment source

Table 2. Well information

No	Name or Type	Elevation	Township-Range	Section/Quarter-section
1	Stockwell	4290 ft MSL	5S20E	sec 7 SWSE
2	Stockwell	4707 ft MSL	3S21E	sec 13 NENESE
3	Stockwell	5030 ft MSL	1S23E	sec 26 SWSW
4	Stockwell	5440 ft MSL	3N25E	sec 22 NESE
5	Site 1 well	5362 ft MSL	2N26E	sec 22 NESE
6	Crossroad well	5120 ft MSL	1S28E	sec 2 NESE
7	Stockwell	4583 ft MSL	6S25E	sec 21 SENE

of the 2.5 to 4 Ma fluvial deposits of the lower Glens Ferry Formation at Hagerman Fossil Beds National Monument. The Big Lost River is missing from the regional stratigraphic record between 4 Ma and the time it was captured by

the Big Lost Trough, after 2.5 Ma (Link et al., 2005).

Pre-Holocene age dates for the Craters of the Moon National Monument (Kuntz et al., 2004) have greatly advanced our understanding

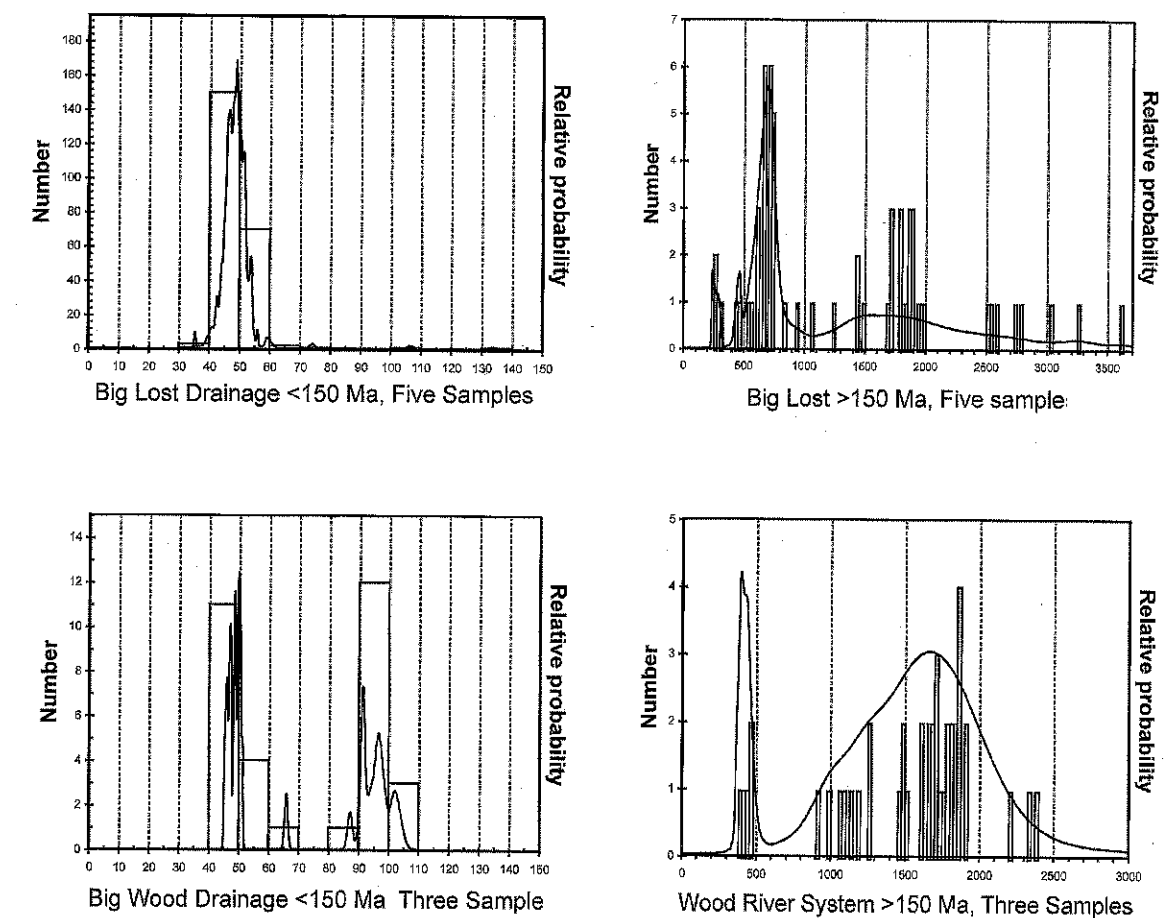


Figure 5. Zircon track age date distributions for the Big Wood and Big Lost Rivers. Sample locations and full data are presented in Link et al. (2005). Samples for the Big Lost River include the Big Lost River near Chilly, Idaho; Antelope Creek near its mouth; the Big Lost River at Hwy 26 Rest area; Big Lost River Pleistocene sand about 2 miles upstream from Hwy 26, and Holocene sand of Big Lost River about 2 miles upstream from Hwy 26. The Wood River samples include Trail Creek above Corral Creek, the Big Wood River south of Bellevue and the Little Wood River south of Carey.

of uplift patterns for active volcanic areas on the Snake River Plain. However, these patterns can not be traced prior to ~0.5 Ma due to the lack of age dates south and west of the monument and the relative poverty of wells and well logs. There are no known dates in the subsurface west and south of well C1A at the southern edge of the Big Lost Trough. It is not currently possible to even estimate a date for the Axial Volcanic High west of the Great Rift. The mixed gravel sediments at elevation 1325 m MSL in the Crossroads Well (well 6, figure 4) indicate that sometime in the Plio-Pleistocene there were river waters at flood at this location on the flanks of the Quaking Aspen Butte swell – but that is all we can say until more data become available. Gravel-bearing sediments in this well are still remarkable when we consider that elevated rift zones accumulate little to no sediment (Anderson et al., 1997, Helm-Clark et al., 2005).

The age of the mixed gravel unit in wells 2, 3 and 5 is also uncertain. Applying a basalt accumulation rate of 33 m/100 ka averaged from data in Champion et al. (2002) and assuming the surface basalts at well 5 date from ~0.5 Ma, then the mixed gravel layer in this well is ~1.2 Ma or older. Given the variability of calculated recurrence intervals, however, it is possible that the accumulation rate is half this, which would date the mixed gravel unit at ~2.4 Ma instead.

There is no evidence for Big Lost River detrital zircon populations in the Glens Ferry Formation at Hagerman below the uppermost units at about 2.5 Ma. If the gravel sediments in the several wells do date from 2 to 4 Ma, the channels they represent may have been captured in playa sinks north of an ancestral Axial Volcanic High. These playa sediments may be represented by multiple clay layers interbedded with subsurface basalts in the area between Wapi and Dietrich (figure 1). This is the most likely explanation that fits both the lack of Big Lost River sediment in the Glens Ferry Formation and the presence of the undated paleo-river channels and sinks in

the subsurface south and west of the Arco and Great Rifts.

ACKNOWLEDGEMENTS

The authors wish to thank Prof. Scott Hughes for his patience while we finished this manuscript and Prof. Dave Rodgers for his review. We also wish to thank Dennis Dunn of the Idaho Department of Water Resources for his help with Idaho's water well database.

REFERENCES

- Anderson, S. R., Liszewski, M. J., and Cecil, L. D., 1997, Geologic Ages and Accumulation Rates of Basalt Flow Groups and Sedimentary Interbeds in Selected Wells at the Idaho National Engineering Laboratory, Idaho, U.S. Geological Survey Water Resources Investigation Report 97-4010.
- Beranek, L.P., Fanning, C.M., and Link, P.K., 2006, Miocene to Holocene landscape evolution of the western Snake River Plain region, Idaho: Using the SHRIMP detrital zircon provenance record to track eastward migration of the Yellowstone hotspot: Geological Society of America Bulletin, v. 118, p. 1027-1050.
- Bestland, E. A., Link, P. K., Champion, D., and Lanphere, M., 2002, Paleoenvironments of sedimentary interbeds in the Pliocene-Pleistocene Big Lost Trough (Eastern Snake River Plain, Idaho), in Link, P. K., and L. L. Mink, eds., Geology, Hydrogeology, and Environmental Remediation, Idaho National Engineering and Environmental Laboratory, Eastern Snake River Plain, Geological Society of America Special Paper 353, p. 27-44.
- Blair, J. J., and Link, P. K., 2000, Pliocene and Quaternary Sedimentation and Stratigraphy of the Big Lost Trough from Coreholes at the Idaho National Engineering and Environmental Laboratory, Idaho: Evidence for a Regional Pliocene Lake during the Olduvai Normal Polarity Subchron, in Robinson, L., ed., Proceedings of the 35th Symposium on Engineering Geology and Geotechnical Engineering, Idaho State University Pocatello, Idaho
- Blair, J. J., 2002, Sedimentology and Stratigraphy of Sediments of the Big Lost Trough Subsurface from Selected Coreholes at the Idaho National Engineering and Environmental Laboratory, Idaho: M. S. Thesis: Idaho State University, Pocatello, Idaho.
- Champion, D. E., Lanphere, M. A., and Kuntz, M. A., 1988, Evidence for a New Geomagnetic Reversal from Lava Flows in Idaho—Discussion of Short Polarity Reversals in the Brunhes and Late Matuyama Polarity Chrons: Journal of Geophysical Research, v. 93, p. 11,677–11,680.
- Champion, D. E., M. A. Lanphere, S. R. Anderson, and M. A. Kuntz, 2002, Accumulation and subsidence of Late Pleistocene basaltic lava flows of the eastern Snake River Plain, Idaho, in Link, P. K., and L. L. Mink, eds., Geology, Hydrogeology, and Environmental Remediation, Idaho National Engineering and Environmental Laboratory, Eastern Snake River Plain, Geological Society of America Special Paper 353, p. 175–192.
- Geslin, J.K., Link, P.K., and Fanning, C.M., 1999, High-precision provenance determination using detrital-zircon ages and petrography of Quaternary sands on the eastern Snake River Plain, Idaho: Geology, v. 27, no. 4, p. 295-298.
- Geslin, J.K., Link, P.K., Riesterer, J.W., Kuntz, M.A., and Fanning, C.M., 2002, Pliocene and Quaternary stratigraphic architecture and drainage systems of the Big Lost Trough, northeastern Snake River Plain, Idaho, in Link, P.K., and Mink, L.L., editors, , Geology, Hydrogeology and Environmental Remediation, Idaho National Engineering and Environmental Laboratory, Eastern Snake River Plain, Idaho: Geological Society of America Special Paper 353, p. 11-26.
- Graf, W. H., 1971, *Hydraulics of Sediment Transport*, New York: McGraw-Hill Book Co, 515 pp.
- Helm-Clark, C. M., 2007, A Conceptual Model of the Geology of the Snake River Plain Aquifer in the Environs of the Big Lost Trough, this volume.
- Helm-Clark, C. M., and Rodgers, D. W., 2004, New 40AR/39AR data from Pleistocene basalts on the East Snake River Plain, Idaho, and their implications for the subsurface structure of the Big Lost Trough: Abstracts with Programs – Geological Society of America, Rocky Mountain/Cordillera Joint Section, April 2004, v. 36, Issue 4, p. 98.
- Helm-Clark, C. M. Ansley, S. L., McLing, T., and Wood, T. R. (2005), Borehole and Well Middle-1823 and Its Relationship to the Stratigraphy of the South-Central Idaho National Laboratory, ICP/EXT-05-00790, US DOE Idaho Completion Project, Idaho Falls, Idaho; 96 p.
- Kuntz M A, Champion, D. E., Lefebvre, R. H., Covington, H. R., 1988. Geologic map of the Craters of the Moon, Kings Bowl, and Wapi lava fields and the Great Rift volcanic rift zone, south-central Idaho. *U S Geol Surv Misc Invest Ser Map*, I:1632, 1:100,000 scale geol map.
- Kuntz, M.A., Downs, W.F., Smith, R.P., and Ruebelmann, K.L., 1989, Geology of the Snake River Plain from Idaho Falls to Arco, Idaho, in Smith, R.P., and Downs, W.F., eds., Snake River Plain-Yellowstone volcanic province: American Geophysical Union, 28th International Geological Congress Field Trip Guidebook T305, p. 48- 49.
- Kuntz, M. A., Skipp, B., Lanphere, M. A., Scott, W. E., Pierce, K. L., Dalrymple G. B., Champion, D. E., Embree, G. F., Page, W. R., Morgan, L. A., Smith, R. P., Hackett, W. R., and Rodgers, D. W., 1994, *Geologic Map of the Idaho National Engineering Laboratory and Adjoining Areas, Eastern Idaho*: U. S. Geological Survey Miscellaneous Investigations Series Map I-2330, scale 1:100,000.
- Kuntz, M. A., Owen, D. E., Champion, D. E., Gans, P. B., Smith, S. C., and Brossy, C., 2004, Geology of the Craters of the Moon 30' X 60' Map Area and New Perspectives on Basaltic Volcanism of the Eastern Snake River Plain, Idaho, in Haller, K. M., and Wood, S. H., eds., Geological Field Trips in Southern Idaho, Eastern Oregon, and Northern Nevada: U. S. Geological Survey Open File Report 2004-1222, p. 136-155.
- LaPoint, P. J. L., 1977, Preliminary Photogeologic Map of the Eastern Snake River Plain, Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF-850.
- Link, P.K., McDonald, H.G., Fanning, C.M., and Godfrey, A.E., 2002, Detrital zircon evidence for Pleistocene drainage reversal at Hagerman Fossil Beds National Monument, central Snake River Plain, Idaho: in Bonnichsen, Bill, C.M. White, C.M., and McCurry, Michael, eds., Tectonic and Magmatic Evolution of the Snake River Plain Volcanic Province: Idaho Geological Survey Bulletin 30. p. 105-119.
- Link, P.K., Fanning, C.M., and Beranek, L.P., 2005, Reliability and longitudinal change of detrital-zircon age spectra in the Snake River system, Idaho and Wyoming: An example of reproducing the bumpy barcode: Sedimentary Geology, v. 182, p. 101-142.
- Ludwig, K.R., 2003, Isoplot/Ex version 3.0. A geochronological toolkit for Microsoft Excel:

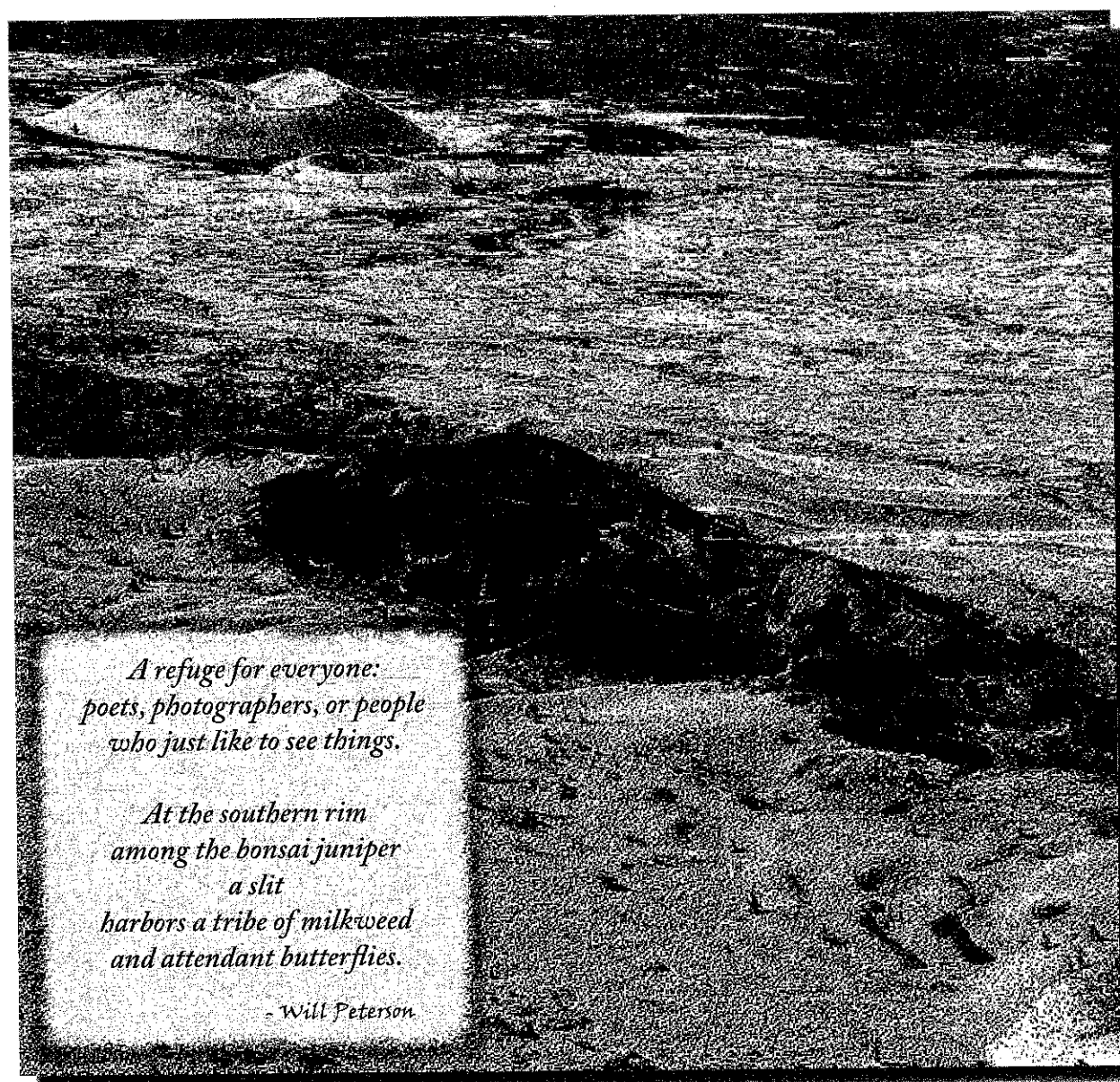
Berkeley Geochronology Center Special Publication No. 1a, 2455 Ridge Road, Berkeley CA 94709, USA.

Williams, I. S., 1998, U-Th-Pb Geochronology by Ion Microprobe, in McKibben, M. A., Shanks III, W. C., Ridley, W. I., eds., Applications of microanalytical techniques to understanding mineralizing processes: Reviews in Economic Geology, v. 7, p. 1-35.

Wood, T. R., Helm-Clark, C. M., Orr, B., and 7 others (2005), Summary Report On The Subregional

Scale Two Dimensional Aquifer Model, ICP/EXT-05-00979, US DOE Idaho Completion Project, Idaho Falls, Idaho; 108 pp.

Wood, T. R., Helm-Clark, C. M., Huang, H., Magnuson, S. O., McLing, T., Orr, B., Rohe, M. J., Plummer, M. A., and Podgorney, R. K., 2007, Operable Unit 10-08 Development Report on the Idaho National Laboratory Site-wide Three-Dimensional Aquifer Model: Report RPT-365, Idaho Cleanup Project, Idaho Falls, Idaho, 279 p.



*A refuge for everyone:
poets, photographers, or people
who just like to see things.*

*At the southern rim
among the bonsai juniper
a slit
harbors a tribe of milkweed
and attendant butterfly.*

- Will Peterson

Photo by Susan Sakimoto & Scott Hughes

Reconstructing a Breached Cinder Cone at Craters of the Moon National Monument and Preserve: A Geographic Information Systems Approach

Cooper C. Brossy

William Lettis and Associates, Inc, 1777 Botelho Dr., Suite 262, Walnut Creek, CA 94596 brossy@lettis.com

Brennan T. Jordan

Department of Earth Sciences, University of South Dakota, 414 E. Clark St, Vermillion, SD 57069

Brennan.Jordan@usd.edu

Duane E. Champion

U.S. Geological Survey, MS-910, 345 Middlefield Rd, Menlo Park, CA 94025 dchamp@usgs.gov

ABSTRACT

North Crater is a breached basaltic cinder cone in the Pleistocene to Holocene Craters of the Moon lava field located within Craters of the Moon National Monument on the eastern Snake River Plain of southern Idaho. Large portions of the cone were rafted away by lava flows issuing from its base between about $2,222 \pm 100$ and $2,400 \pm 300$ years ago. The volume of cone material rafted from North Crater was documented utilizing a Geographic Information Systems (GIS) approach and far exceeds the volume which the breach in North Crater can contain. The breach in the northwest side of North Crater has a volume of only $1.23 \times 10^6 \text{ m}^3$. Putting the $46 \times 10^6 \text{ m}^3$ of rafted material back onto the current North Crater edifice would create a paleo-North Crater with a volume of $88 \times 10^6 \text{ m}^3$, requiring a footprint area of $1.52 \times 10^6 \text{ m}^2$, a radius of 700 m, and a height of 175 m. It is possible, however, that one large, monogenetic paleo-North Crater that size never existed. An alternative model is that a series of smaller paleo-North Craters were built at this location and destroyed by eruptions causing block rafting, the last of these being the existing, breached North Crater.

INTRODUCTION

Geologic Setting

Craters of the Moon National Monument and Preserve (CMNMP) is situated along the Great Rift, an 85 km-long, 2 to 8 km-wide volcanic rift zone in the eastern Snake River Plain of southern Idaho (Kuntz and others, 1986; Pierce and Morgan, 1992). The Great Rift has produced the Kings Bowl, Wapi, and Craters of the Moon lava fields (Kuntz and others, 1986). The latest Pleistocene to Holocene Craters of the Moon (COM) lava field comprises 8

eruptive fissure systems, 25 cinder cones, and more than 60 lava flows covering $\sim 1,600 \text{ km}^2$ (Kuntz and others, 1986).

North Crater is a breached basaltic cinder cone in the northern portion of Craters of the Moon lava field (Kuntz and others, 1986). Five lava flows, the Highway, Devils Orchard, Serrate, Big Craters Northeast ($2,400 \pm 300$ yrs B.P.), and North Crater flows ($< 2,205 \pm 25$ yrs B.P.), erupted from vents within, or nearby, North Crater (Figure 1) (Kuntz and others, 1989). Three of these flows, the Highway,