Duane Champion

SG+G Panel Meeting of NWTRB
Las Vegas, NV 9/15/92

Good Morning. In my talk this morning I would like to bring you up to date on our volcanic hazard work in the USGS, as it relates to the suitibility of the Yucca Mountain Repository. I have now completed all laboratory work on post-Miocene basalt centers near the NNTS and can relate those results. In addition, I will discuss some new paleomagnetic work at Sunset Crater Arizona, and at Hidden Cone, NW of Beatty, which has precipitated some geologic reevaluation. I will also use the paleomagnetic data we have generated to evaluate two models of episodic behavior that have been presented for the million year old centers of Crater Flat and for Lathrop Wells. (I will finish with a discussion of the characteristics of the SE flank of the Lathrop Wells cone.) By the end of my talk I will show that the paleomagnetic data still fails to find the signature of time in the remanent directions recorded in these basaltic centers, signifying the misleading nature of the polycyclic model.

John Geissman explained yesterday the paleomagnetic analysis that is useful to the study of these volcanoes, so I won't repeat much except the basics for those who might not have been here. Paleomagnetists collect samples in volcanic units to ascertain the inclination and declination values recorded in those units. The technology is 30 years old and very robust. The fact that John and I agree... **(Hawaiian SV)** Records of the directional change thru time, such as this from Hawaii for the last 3000 years document the rapid, and seemingly random nature of this geomagnetic secular variation. VIEWGRAPHS ↑**(77 western USA directions)** If you lack detailed time control then you can still collect directions of magnetization, and not be able to draw a path of variation thru time, but still examine the overall range of of the data. On this diagram, of Holocene directions I have outlined the usual outer range of secular variation as ±25° of angular variation with this roughly triangular shape, which will appear on several subsequent diagrams. **(K=30 diagram)** Theoretically, paleomagnetism views the variation as circularly distributed and uses an inverse measure of dispersion called kappa to describe the variation. Here you can see that the distribution for kappa = 30, a good number for

Don, I'm sure you are correct in your analysis of the secular variation rate from Robin Holcomb's paper.

dispersion due to secular variation, is clotted toward the center, as the real data was in the previous slide, with 95% of directions expected within 30° of the mean direction.

As John explained yesterday, similarity of magnetic directions from a number of volcanic units can be used as evidence that they might have formed at the same time, while different directions are hard evidence that the sampled units are not the same age. Polycyclic volcanism, which is thought to manifest in eruptions at a volcanic cinder cone center that are separated by up to 10,000's of years, should produce multiple magnetic directions in the volcanic pile aggregated through time. Let's review the basaltic centers of post-Miocene age and located near Yucca Mountain and see what they record.

Basaltic Centers

We'll look at the centers oldest to youngest. **(Thirsty Geology)** A recent reevaluation of the stratigraphic position of Thirsty Mountain has suggested to Dave Sawyer, Scott Minor, Rick Warren Bob Fleck and the other members of the USGS-DOE Weapons Project that the 8 Ma age associated with that shield volcano is incorrect. They have embarked on a chemical and stratigraphic study which is being assembled in manuscript form now. **(Thirsty K-Ar)** Bob Fleck, who by the way is here today, also has done 3 pairs of K-Ar ages, shown in this table, which document an age of 4.63 Ma for the shield. **(Thirsty directions)** Mark Hudson of the Weapons Project and I have collaborated on getting some paleomagnetic data from the S, W, N and summit areas of the shield, and the mean directions are shown on this diagram. They are reversed in polarity and all show SSE declinations and moderate inclinations. Use of a statistic presented by Bogue and Coe to evaluate the randomness of a population of magnetic directions suggests only 1 chance in 100,000 that these five directions were randomly acquired in time. So we can show that large volume basaltic eruptions have occurred in the general vicinity of the repository site, long after the silicic eruptions were finished, and that the duration of the eruption was short compared to the rate of secular variation. There is no hint of polycyclic volcanism in the data. We note that Bruce Crowe has already included Thirsty Mountain in his CFVZ

(SE 3.77 Ma flow distribution) No polycyclic model has been presented for the relatively voluminous basalt eruptions in the SE corner of Crater Flat which occurred at 3.77 Ma. Under the assumption that it may be offered in the future, we have taken 6 sites in these lavas, including one in the upfaulted block on the W side of Yucca Mtn. These lavas are eroded and sometimes buried by alluvium, but good paleomagnetic sites were found in vent and lava flow facies. **(3.77 Ma directions)** We find reversed polarity in these sites, appropriate to the Gilbert Epoch, and again we see well-grouped data, but this time close to the limit of usual secular variation. By moving 10°-12° from the average reversed polarity direction, the Bogue and Coe statistic begins to suggest powerful correlations, with the odds of these 6 sites being a random draw of secular variation at 1 part in 100 million.

(Buckboard Mesa geology) Buckboard Mesa with an age of 2.92 Ma is the next youngest basaltic center near Yucca Mountain, and it too is relatively voluminous. It has been included or excluded from volcanic hazard consideration, depending on who you read, so we felt compelled to collect paleomagnetic data to evaluate its possibly polycyclic nature. **(Buckboard directions)** Three sites taken in S, central and N areas of the flows all record a steep, westerly declined normal polarity direction, appropriate to a time frame within the Gauss Epoch. These directions are at or outside the usual range of secular variation, so althrough we have only 3 sites the odds they are random in time is only 3 parts in 100,000. Again we have evidence of a short duration eruption at Buckboard Mesa. One of our sites was taken in a flow located just N of Danny Boy Crater, a flow which was discussed at the last panel meeting as possibly locally vented and not from Scrugham Peak. The lava we sampled was oxidized and vesiculated in a manner which suggests a flow of remobilized spatter, though no obvious vent structures presented themselves. It's direction was identical to those from the main flows, so it shares the same eruptive episode, even if it is locally vented.

The reasons cited for its exclusion from CFVZ were its slightly [illegible] and voluminous nature. As this Mountain has been included, the reason for excluding BM not longer exist and CFVZ need to be further redrawn.

(1.1 Ma center distribution) If we jump to the western side of Yucca Mountain, we find the next youngest basaltic centers, those of the

1.1 Ma vents on the floor of Crater Flat. There are 4 principal eruptive centers, up to 12 km apart, aligned in a gentle arcing trend to the NE, with the northernmost vent at the W foot of Yucca Mtn. itself. Samples have been taken in vent areas, from perched lava lakes, dikes and from lava flow outcrops. Until recently no geologic maps for these centers have been presented, but polycyclic models were suggested at the last meeting of this panel based on satellitic scoria mound distribution and on a single anomalously high K-Ar age from the northernmost center. **(1.1 Ma directions)** The directions of magnetization found from 20 sites in these 1.1 Ma centers have reversed polarity, with somewhat steep inclination values, and they group well. By comparing the least common and most common site directions, it is possible to bracket the range of probabilities of randomness in this data, and they range from the 10^{-16} to the 10^{-34} level. A more conventional geologic model would suggest that the 4 different basaltic centers would each be monogenetic and independent eruptive events. **(1.1 Ma directions by edifice)** This plot shows the mean directions for averages of individual sites at each center and demonstrates once again the very strong grouping. They group so well that there is only 4 chances in a million that they are randomly selected from secular variation. Not only do we not have evidence of polycyclic eruptions, but we also have evidence that the four 1.1 Ma centers share the same age. **(K-Ar 1.1 Ma age table)** This paleomagnetic conclusion was heralded by earlier conventional K-Ar dating, in that data from 26 extractions shows very similar age results for the four centers, and an overall age of 1.04 Ma.

(Smith-geologic map of Red and Black cones) Geologic maps of the Red Cone and Black Cone centers were recently presented at a meeting of the ACNW on Quaternary dating and also in a journal article. In the article on hazard probabilities, there was concern expressed in regard to ascertaining episodicity within these 2 basaltic centers. I have shown our paleomagnetic site distribution on this geologic base, and can report that four of the indicated volcanic units at each center, have at least one paleomagnetic site in them. We have already seen that the directions of magnetization are very grouped. There ~~was~~ were only 6 chances in 1000 that the mean direction of Red Cone was different from Black Cone. The

And Yesterday we heard Frank Perry say that the N + S flows of Black cone were not chemically related and indicated they must be due to two time separated episodes of Polycyclic Volcanism

Bogue and Coe statistics on the mean directions calculated for each of the four map units at each center are 3 parts in 10,000 for Black Cone and 3 parts in 100,000 for Red Cone. There is little possibility that the new stratigraphic units at Red and Black Cones are separate in time. Care must be taken in the volcanic hazard evaluation of the 1.1 Ma centers, when you tally the number of eruptions. There are 4 is you are evaluating a spatial term, but only one if you are counting episodes in time.

For those keeping a tally We are not in consensus if significant this division is required for Frank's interpretation

(photo of Sleeping Butte cones) The two relatively low-volume cinder cones located just NW of Thirsty Mtn are included within the NW trending Crater Flat Volcanic Zone, though they are 47 km from the repository site. What you see in this photo is Little Black Peak in the left center, and Hidden Cone perched on the northern flank of the much older and silicic Sleeping Butte. **(Little Black Peak geology)** Geologic maps of these cones have recently been presented and I have shown the location of my sites on that format. I have taken samples from the cones themselves, shown in pink, **(Hidden Cone geology)** and from sites in spatter, dikes and lava flows. Polycyclic eruption models, based on detailed geomorphic and soils analyses, have been suggested for these cones with episodes at about 285, 200, 100 and 10 ka.

(Sleeping Butte directions) The distribution of normal polarity directions is again limited, although the color coding suggests that some difference in direction exists between Hidden Cone and Little Black Peak. **(Sleeping Butte average directions)** Looking at mean directions, calculated from the individual site means for each cone, we find they have a small 4.5° angular difference. Our randomness statistic suggests there is only a 7% chance this difference has any significance in time. **(K-Ar age table)** We can support the idea of a single essentially monogenetic eruption episode, if we look at the existing K-Ar age data for samples from the two cones, which Bob Fleck has averaged for me. With 14 extractions from Little Black Peak, and 12 from Hidden Cone, a single episode at 353,000 years is indicated. The new $^{40}Ar/^{39}Ar$ age that Brent Turrin just described also supports this age assignment. The paleomagnetic data constrains this episode to about a century of time.

Recent geologic work by Dave Sawyer and Bob Fleck of the DOE Weapons Project has added to our understanding of the Hidden Cone

eruption story. They noted the existence of a flow to the N. of Hidden Cone, not reported previously. **(Airphoto of Hidden Cone)** This airphoto, from BLM sources, shows this young flow with tongues reaching off to the NW and to the NE. **(Hidden Cone new directions)** Three new paleomagnetic sites have been located in these northern flows and they are shown in green here, against the backdrop of the red mean direction for Little Black Peak and the Blue for Hidden Cone. What you should note is that the new northern Hidden Cone sites agree better with the Little Black Peak mean direction than they do with the previous sites from Hidden Cone.

I have two interpretative choices. I can embrace these new directions as a manifestation of dispersion within Hidden Cone and just average them in with the other 6 sites. This will drastically reduce the angular difference between the means of the two centers, and improve the interpretation of a monogenetic origin common to both centers. The interpretation I prefer is that the northern Hidden Cone flows represent the same exact episode as that which produced Little Black Peak, and that subsequent eruptions emplaced the eastern flows at Hidden Cone. I say subsequent because the site at the cone rim of Hidden Cone (and presumably one of the last eruptive products) agrees with the eastern flow.

The grapevine has suggested that a high degree of resistence to the discovery of these northern flows exists, tied to the thought that the 9 Ma flows have been mistaken for the flows of Hidden Cone. **(K-Ar age table)** This is analytically impossible, as the new $^{40}Ar/^{39}Ar$ age that Brent reported is on these northern flows, and the older flows are very well behaved with a range of ages between 9.30 and 9.36 Ma for a stratigraphy of 3 different basalts, sandwiched under, between, and over the Pahute Mesa and Trail Ridge Tuffs. Confusion is impossible here. A new geologic map of Hidden Cone is being prepared, the photogrammetry is done and it is being inked. It will be released as either an Open-File Report, or a Miscellaneous Field Studies map in the future.

(Lathrop Wells geology) I won't dwell on the ~~old~~ Lathrop Wells data, which is now complete, except in quick review. This map shows the

location of the 26 sites taken in these flows and spatter deposits. There are 7 different eruptive units mapped here. **(Turrin Geology)** A simplification of the map suggests there are two easily recognized units, one older and mantled by cinders, and a younger flow to the east, shown in green, which is unmantled by cinders. **(Lathrop Wells directions)** These are the directions of magnetization derived from Lathrop Wells units. They are color coded by unit assignment, but cluster so strongly they are difficult to resolve. Little overall paleomagnetic variation is indicated from these sites. **(Lathrop Wells unit averages)** When you average by geologic unit, small angular differences emerge. We feel these differences are real and require some 50-100 year duration for the Lathrop Wells eruptions. If we assert these means are significantly independent in time, we can limit that possibility to 1 part in 10,000.

(Ql_6 photo) As John Geissman pointed out yesterday, all is not goodness and light in paleomagnetically sampling the Lathrop Wells center. This photo shows the blocky outcrop of flow Ql_6, in the vicinity of the old cribbing on the SW side of the center. I placed a site in the biggest and deepest rooted blocks in this area, under the hope of obtaining a coherent result. **(Ql_6 directions)** This hope was not realized as you can see by these results and the very large circle of 95% confidence. Detailed stepwise thermal demagnetization revealed no partial thermoremanence in the samples, indicating this dispersion occurred in cold blocks jostling on the surface of the flow. The overall result is not without some coherence, with the mean direction clearly of viable normal polarity, but it is utterly useless to secular variation study. John Geissman has produced coherent Ql_6 data from other outcrops and they show a direction which is insignificantly different from our earlier work.

I wish I had had a D 9 dozer to rearrange the outcrop for I could only

(new Lathrop Wells Geology) A new tripartate chronostratigraphic framework for the Lathrop Wells center was presented by Crowe et. al. this spring, which grouped previously designated geologic units. They are shown here, with the color coding of blue for the eldest, green for the intermediate and most broadly distributed and red for the youngest unit, essentially the cinder cone itself. It was incorrectly asserted that my distribution of sites, shown on this figure, as blue and red dots, were inadequate to evaluate possible time differences between the 3 chronostratigraphic units. This assertion is untrue, with the possible exception of the

cone, for which I have only two sites of 43 samples total. **(Lathrop Wells I, II, III)** I have reaveraged my sites in accord with the new stratigraphic model, and they are shown here with the same color code as the previous slide. The angular range of the Lathrop Wells data which once was 4.5° has been reduced to 2° with a zigzag pattern of movement through time. The Bogue and Coe statistic suggests there is only one chance in 10,000 that these new chronostratigraphic units are random samples of secular variation. We prefer our original analysis, reported in Science, with the identification of a short time break in eruptions at about 125,000 years ago.

Jack Evernden, here is a perfect example of your concern expressed yesterday. very which all occurred

(Pisgah and Amboy directions) We have studied other youthful basaltic centers in the vicinity of Yucca Mountain, such as those at Pisgah and Amboy Craters. The pattern is now easily recognizable to you all [redacted] Both centers group well with the 3 steeply magnetized sites from Pisgah nonrandom at one part in 10,000, and the 5 very shallow sites at Amboy nonrandom at 6 parts in 100 billion. These are not polycyclic lava fields.

(Kelley geology) And just to show that others have produced the same sort of paleomagnetic work from basaltic centers, we have John Geissman and his students work at the Albuquerque volcanoes as an excellent example. This geologic map by Vince Kelley shows vents in an alignment at least 4 km long and flows broken into 8 geologic units. Frankly, it looks like a wonderful candidate for polycyclic volcanism to me. **(Geissman directions)** John's directions document extremely unusual, but tightly grouped, directions for lava flows of Brunhes Epoch age, as [redacted] they are over 120° from the expected normal polarity direction, here shown by a star. My computer algorithm for the Bogue and Coe statistic shows only 6 digits of information, and when I ran the Albuquerque volcanoes data the answer came up as all zeros. I can thus say for sure that the probability of random acquisition of these 8 directions is less than 1 part in 10^{-42}. Other trials suggest the real number is less than 10^{-300} power. I think we know from this data that this center was formed during a quick monogenetic event, and the polycyclic model is not indicated once again.

(Cima A cone) Yesterday, Steve Wells presented a new geologic map for the vent area and made comparisons of the stratigraphy there to the Lathrop Wells cone. of the Cima A cone. This vertical photo shows the youthful appearing cinder cone and flow of Cima A. Six paleomagnetic sites were located in lava flow and vent facies outcrops, including the cone rim. Two sites were located in deposits proximal to the Qv2 vent, which is thought to be a source of tephras older, and separated by a soil, from tephra deposits of the Qv3 vent. (Cima Directions) The paleomagnetic results dictate that all younger Cima A ~~[can be traced to the source]~~ eruptive products share a single direction of magnetization. A randomness test on those directions, which are 25° shallower than the average normal polarity direction, returns odds of 1 in 100 trillion

they are random. We are in direct contradiction to Steve's interpretation of two young Cima eruption (Sunset Crater). We feel that data taken from Sunset Crater, Arizona are excellent analogues to the short eruption duration of basaltic centers near Yucca Mtn. (Sunset directions). New sites have been located in the Kwaa-a flow and in the flows of unit 512 and they have confirmed and tightened our short record of stratobound secular variation. Here we know these directions were acquired in a time frame between 1065 and ≅900 AD. Tree ring dating confirms enduring eruptions. 1000's of years as disturbances in the growth pattern of trees of Flagstaff are not available to produce the directional variation of polycyclic volcanism (VGP's). The regional record of archaeomagnetic variation passes right thru the directions, in the proper chronologic order.

It was stated yesterday that Brent at T came to declare a cone apron for Lathrop Wells on the basis of our granulometry measurements. It was actually through an entirely different route. (Lathrop Wells, 1982) This is the topography of the 1982 7.5 minute topo map. In pink I have shown the area of quarrying. (1987 topo) By 1987, the rate of quarrying accelerated, so we asked a topographer in our Natl Mapping Division to recontour the quarry area. Shown in blue is the pit area where the controversial tephras, shown as a red line, lie. These deposits thicken to the NW, along the line of the outcrop (1959 contour map) He also contoured a 1959 using air photos to produce this map, which has the quarry then shown in pink, an area of sand overburden which is skinned back in yellow, and in blue is the location of the pit (ca 1987). You can see it is below the break in cone slope, but still close to the contours follow cone shape.

processes which usually form core apron deposits. This proximity is the explanation of the NW wand thickening of the tephra enclosing stratigraphy.

Paleomagnetic studies in basaltic centers near Yucca Mtn systematically fail to show the paleomagnetic directional diversity that 1000's or 10,000's of years would produce. Coincidence cannot explain this failure, given the total # of trials I have performed. The eruption durations must be very much shorter, on the order of years to a century. The petrologic models, which are now insisted to last 1000's of years to produce variation require revaluation. At this point the controdicts reveal Little consensus, with the vitality of polycyclic volcanism in the balance.