Structural controls on cave development
Oregon Caves National Monument
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Purpose: The goal of this study was to examine in detail the role faults, fractures, and bedding planes have on cave passage development at Oregon Caves National Monument. Field measurements from the cave were compared to the orientation of passages measured from the GIS map of the cave system to determine which, if any, structures are playing a dominant role in cave passage development.

Understanding the interaction between water and planes of weakness in the marble (such as faults, fractures, and bedding) is vital to the study of the erosional processes that formed Oregon Caves. As rain water passes through the decaying plant material on the surface of the earth, it picks up the carbon dioxide released by plant material to form carbonic acid. The acidic solution then makes its way down through the marble along planes of weakness, dissolving the marble along the way, and creating passageways. Thanks to this dynamic process, visitors to the Oregon Caves are able to walk through the interconnecting passageways, or widened cracks in the marble.

Previous Work: No previous detailed structural studies were found for Oregon Caves National Monument. During the initial cave inventory in 1993, faults, dikes, chert and argillite interbeds, and visible jointing were measured and mapped, but neither the raw data nor report could be found. A grant proposal from University of Oregon (Fault Zone Geometries and Cave Morphology at Oregon Caves National Monument, Oregon: 1997) for a similar study as this is on file at ORCA but no accompanying reports or publications could be found.

Methods: Before any data collection began, the definitions of each of the structures to be studied and a method for data collection had to be established. In order to be included in the data set, planes of weakness had to be considered “major” structures and important to the development of cave passageways. It was decided that each structure had to fulfill one or both of the following requirements: 1. The structure had to be visually continuous throughout all or the majority of the room. 2. The structure had to be part of a parallel set. Once a “major” structure was identified, it was measured (strike and dip orientations) and added to one of the following three main classifications:

Bedding: Bedding, or the relict planes of weakness between each layer of limestone before metamorphism, was to be distinguished by continuous chert interbeds or graphite laminations in the exposed marble.

Faults: It is very probable that there are more faults in the cave than made it into this classification but offset was covered or not visible. In order for a plane to be classified as a fault, there had to be visible displacement along the plane. Acceptable evidence for displacement was considered to be offset chert or graphite planes, slickenlines, or tension gashes (Figure 1).

Fractures: Those planes of weakness that did not fall under the previous two designations were labeled fractures. Though bedding was probably not included in this data set, this classification undoubtedly includes not only joint sets but also faults with no definitive displacement.

In addition to measurements taken from the cave, several days were spent in the field taking measurements from the marble exposed at the surface. The same definitions and requirements were applied to the collection of this data set.

Other structures: There were several other structures found and measured in the cave, but none of them constitute a big enough data set to be considered a significant part of the structural study. Dikes, like the one protruding from the wall in the Ghost Room are briefly discussed in the following sections. Thought not discussed in detail, dikes and the one lithologic contact are included in the faults, fractures, and bedding data for ArcGIS under the basedata;cave;formations database and are available for examination.

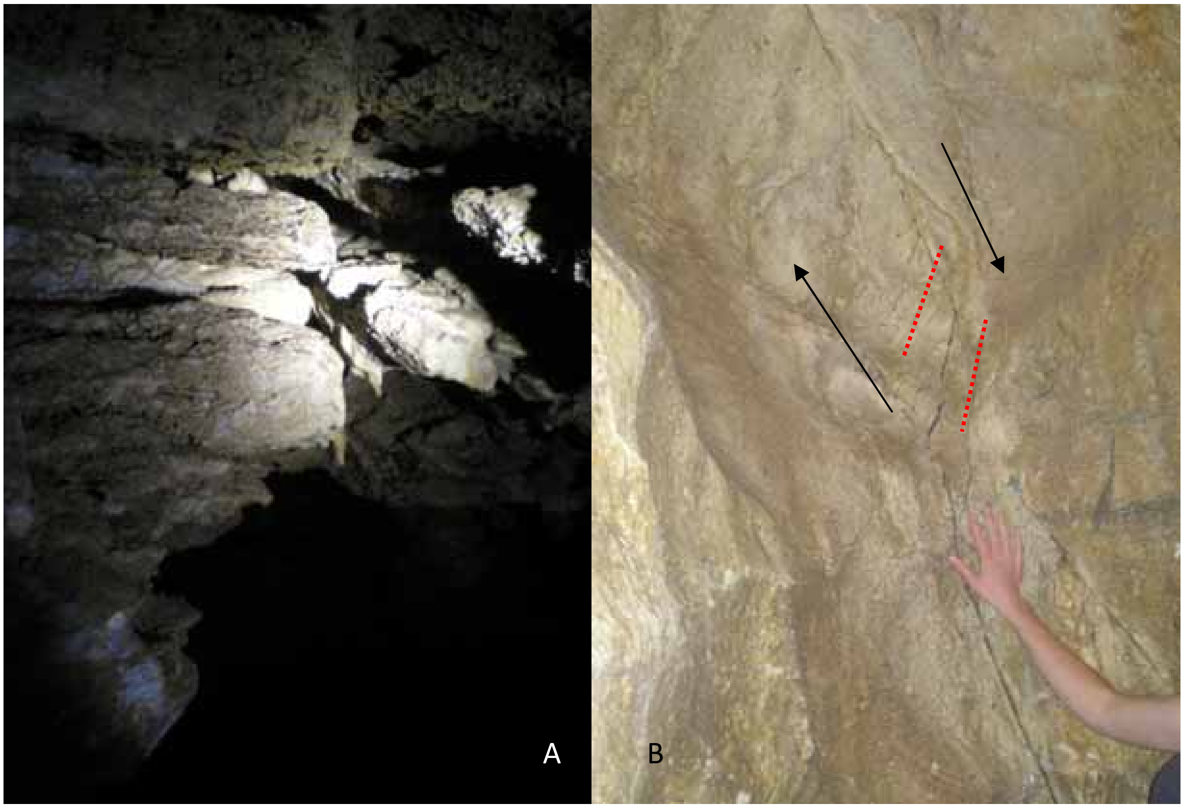


Figure 1: Examples of the structures used to classify faults from fractures in the cave. A: Offset chert interbeds in the Wind Tunnel indicate fault movement. B: Looking NE from Jacks Pass. Tensions gashes (red dashed lines) connect two fault planes indicating a normal sense of movement along the fault zone (indicated by the arrows).

Data:

Rose Diagrams: Rose diagrams were constructed for bedding (inside and outside the cave), fractures (inside and outside the cave), faults, dikes, passage orientation, and a cumulative diagram of all fractures and faults using a ten degree interval on Adobe Illustrator. Each concentric circle in the diagram represents a given number of measurements taken for any of the ten degree increments. The specific value is indicated.

Cave passage orientations were measured directly from GIS data and without any associated dip. As a result, all measurements reflect a strike of less than 180 degrees. Passageways are most commonly oriented NE (SW) or SE (NW) with few striking the cardinal directions (Figure 2; Plate 1).

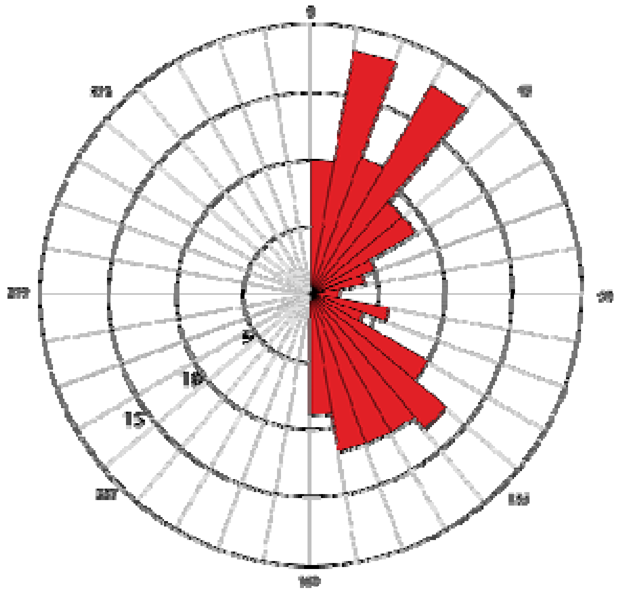


Figure 2: Rose diagram showing orientation of passages. No dip is associated with measurements, so all strike values were taken to be under 180. Number of measurements taken at each 10 degree interval indicated outside representative circle.

Bedding orientation is surprisingly uniform throughout (and above) the cave, striking NE (Figure 3; Plate 2). Variations in strike are extremely localized and tended to occur near small-scale folding of chert beds.

Fracture orientations are greatly varied, but fit into three, general fracture sets: 120-160 degrees (Plate 3), 240-320 degrees (Plate 4), and 330-50 degrees(Plate5) (Figure 4, 5). Many fracture measurements may likely be faults, but many outcrops are not conducive to viewing displacement along chert or graphite beds. If fault measurements are included within a plot of the fracture sets, a SE orientation is clearly dominant with the two other fracture sets still present to a lesser degree indicating many of those structures defined as fractures may actually be faults (Figure 4). Faults (with visible offset) have a strong trend to the SE (Figure 6; Plate 6). At particularly visible outcrops, these faults were normal oblique.

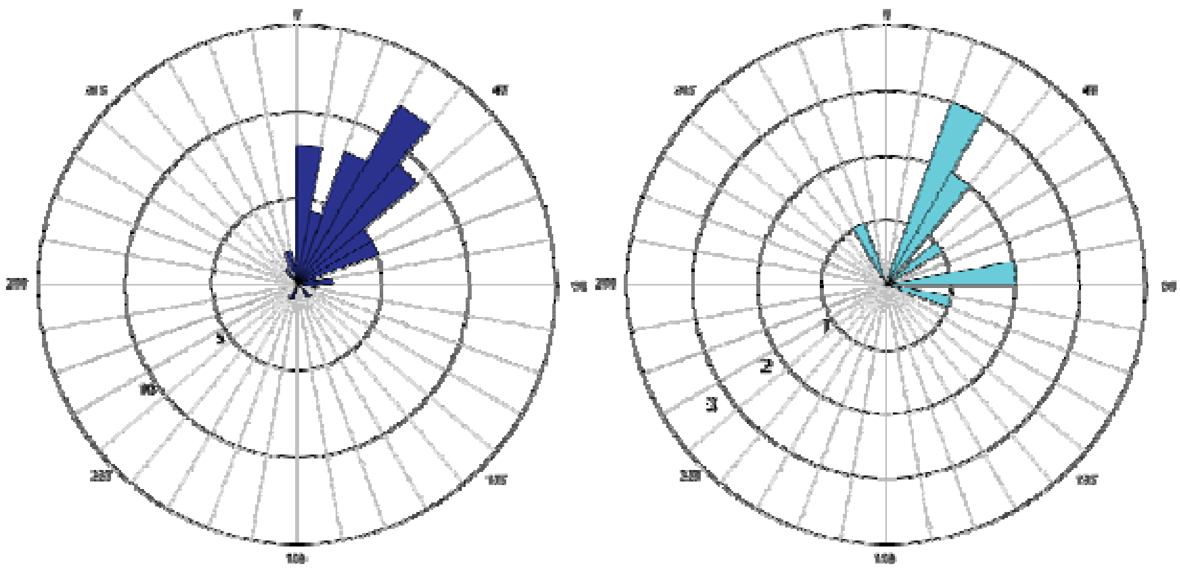


Figure 3: Rose diagram on left corresponds to bedding within the cave (dark blue) and diagram to right corresponds to bedding outside the cave (light blue). Data set from inside the cave is far more comprehensive.

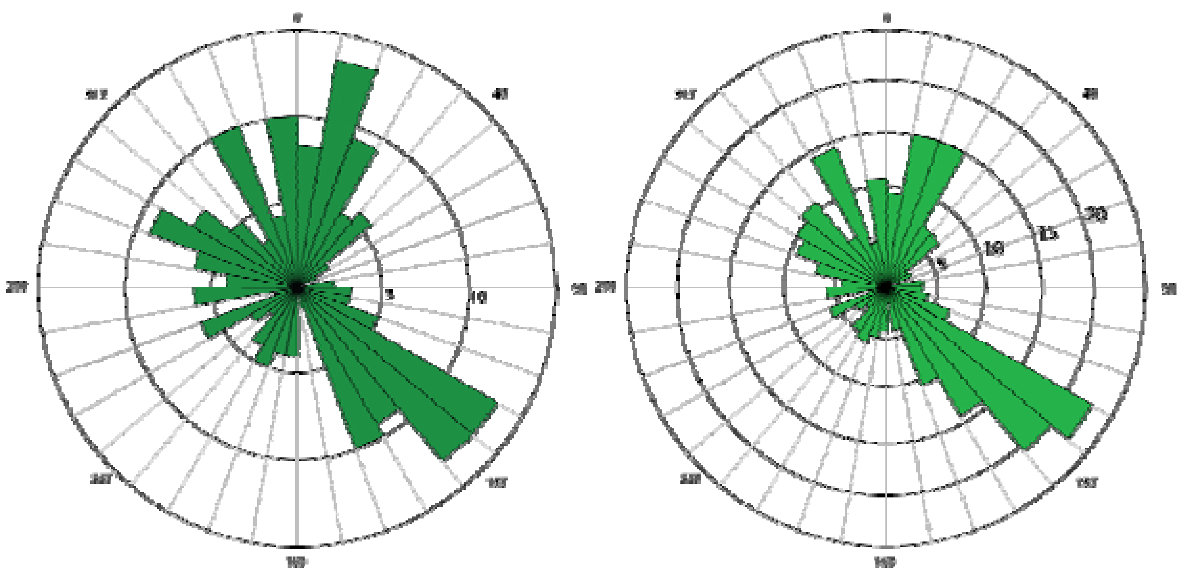


Figure 4: Fracture orientations from inside the cave are plotted on rose diagram on left, cumulative rose diagram of all fractures and faults (both in and outside the cave) are shown on right

Figure 5: Looking south at four fracture sets exposed in the South Room. All fractures in this photograph fall into one of the three fracture sets determined from the rose diagrams. 1: Flat face oriented 261/76N
2: 350/77 E
3: 151/55 SW
4: 130/75 SW

With the exception of one measurement, all the dikes have a strike along a SE/NW line. This trend is roughly in line with two out of the three major fracture set orientations (Figure 6), but much more study is needed to understand the full nature of these dikes as, in at least one outcrop, they appear clastic. The outlying measurement, however, could be better described as a sill than a dike.

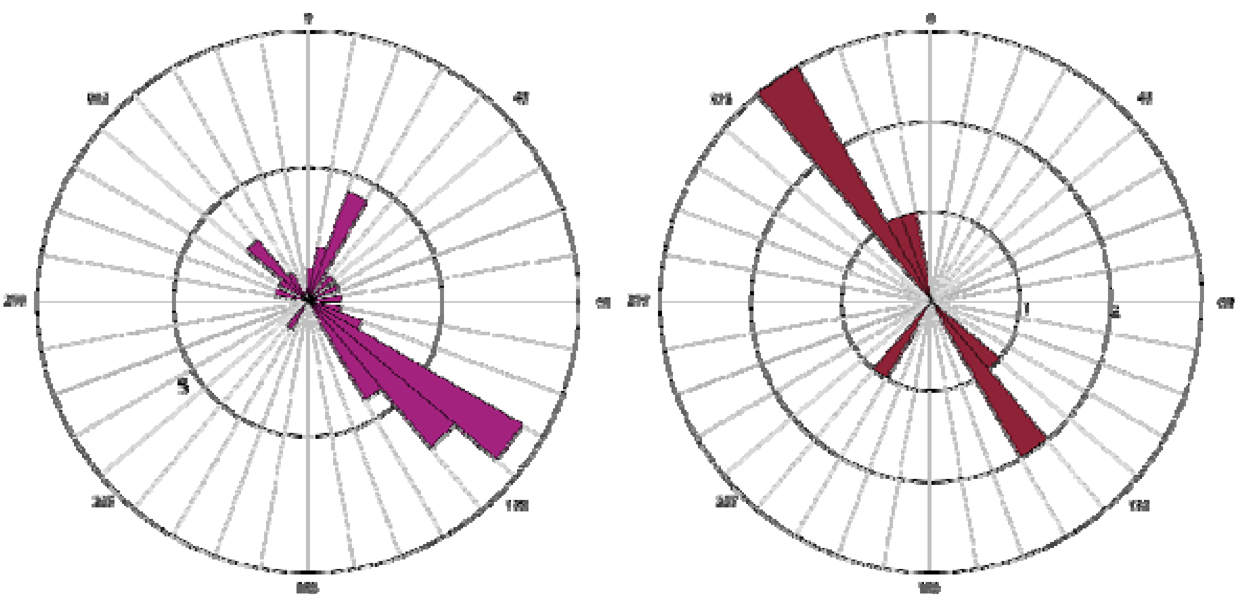


Figure 6: Faults, with discernable displacement, are plotted on left rose diagram. Dike orientations are on right. Outlying measurement has a strike of 215 degrees.

Stereonet Diagrams: Using StereoWin 1.2, created by Richard Allmendinger (http://www.geo.cornell.edu/geology/faculty/RWA/programs.html), average values for the various structures were calculated for both the surface and cave data sets using the Scatter Plot, Mean Vector, and Great Circle functions.

Bedding measurements in the cave and on the surface are fairly consistent in strike as well as dip. Despite the complex deformational history of the area, bedding in the marble block of Oregon Caves dips shallowly to the southeast. Averages for the cave and surface data sets are 36/22.2 SE and 42.5/26.6 SE respectively (Figure 7).

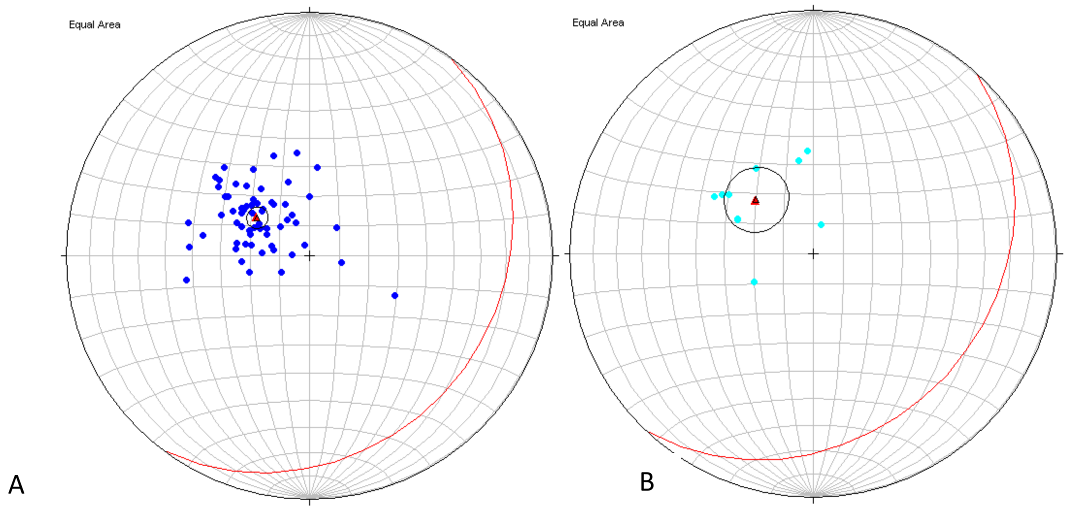


Figure 7: Stereonet diagrams of bedding. Red line indicates average plane calculated from the StereoWin 1.2 program A: Bedding in the cave averages 36/22.2 SE. B: Bedding on the surface averages 42.5/26.6 SE.

Calculating averages for the fracture data sets was not as straightforward as for bedding. No meaningful average could be calculated for the entire data set because there is such a wide range of strikes, so each data set was split up into three fracture sets based on the rose diagrams. All of the measurements for the surface data set fit into one of the three fracture sets designated, but some of the measurements from the cave data set were not included in any of the three fracture sets. Fracture sets for the cave data set were designated based on the number of measurements for each ten-degree range of strikes. Only those strike ranges with five or more measurements were included in the fracture sets (Figure 4).

Three pairs of correlative fracture sets, one set from in the cave and one set from on the surface, were identified and compared. Though the strikes vary, the dips for each pair of fracture sets are remarkably similar. Cave fractures striking between 330 and 50 average 8.7/63.2 SE while surface fractures striking between 20 and 40 average 30.3/65 (Figure 8, 11). Cave fractures striking between 120 and 160 average 138.4/75.6 SW and surface fractures striking between 130 and 210 average 163.3/73.7 SW (Figure 9, 11). Cave fractures striking between 240 and 320 average 285.8/72.4 NE and surface fractures striking between 300 and 340 average 323.2/72.3 NE (Figure 10, 11). Strikes for each correlative fracture set may vary as much as they do because of the small data set from the surface. If more fractures on the surface were measured, the average strikes for each fracture set may be more similar to the corresponding strike from the cave data set.

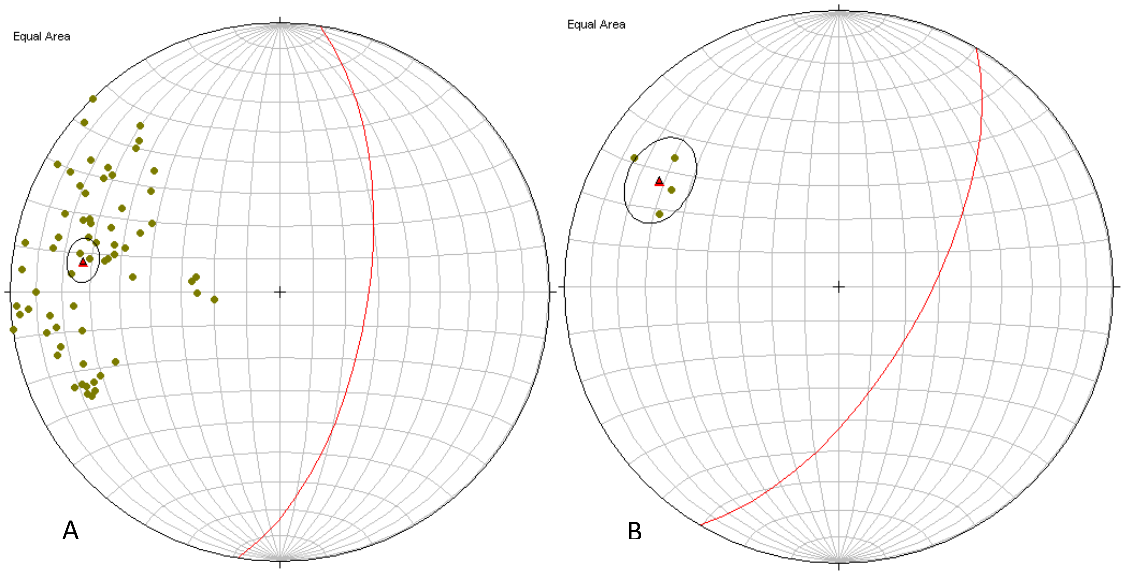


Figure 8: A: Cave fractures striking between 330 and 50 average 8.7/63.2 SE. B: Surface fractures striking between 20 and 40 average 30.3/65 SE.

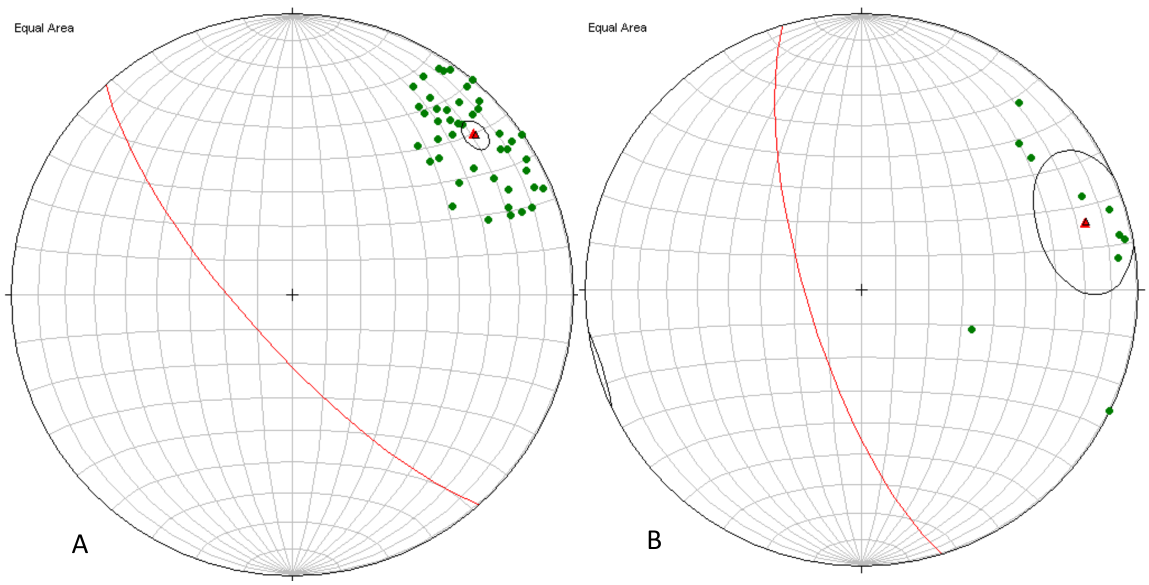


Figure 9: A: Cave fractures striking between 120 and 160 average 138.4/75.6 SW B: Surface fractures striking between 130 and 210 average 163.3/73.7 SW.

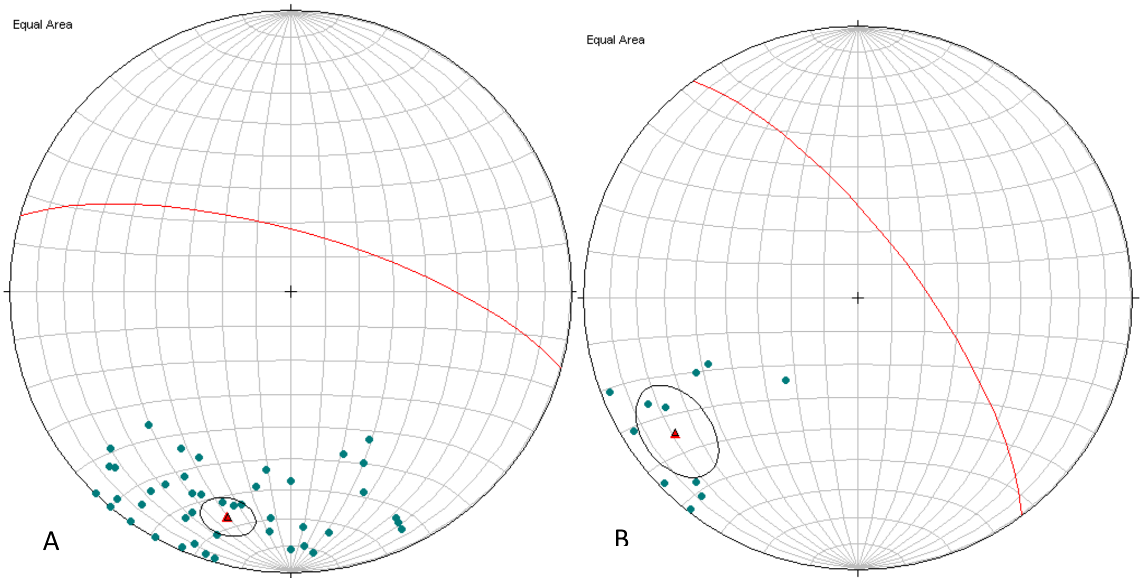


Figure 10: A: Cave fractures striking between 240 and 320 average 285.8/72.4 NE B: Surface fractures striking between 300 and 340 average 323.2/72.3 NE

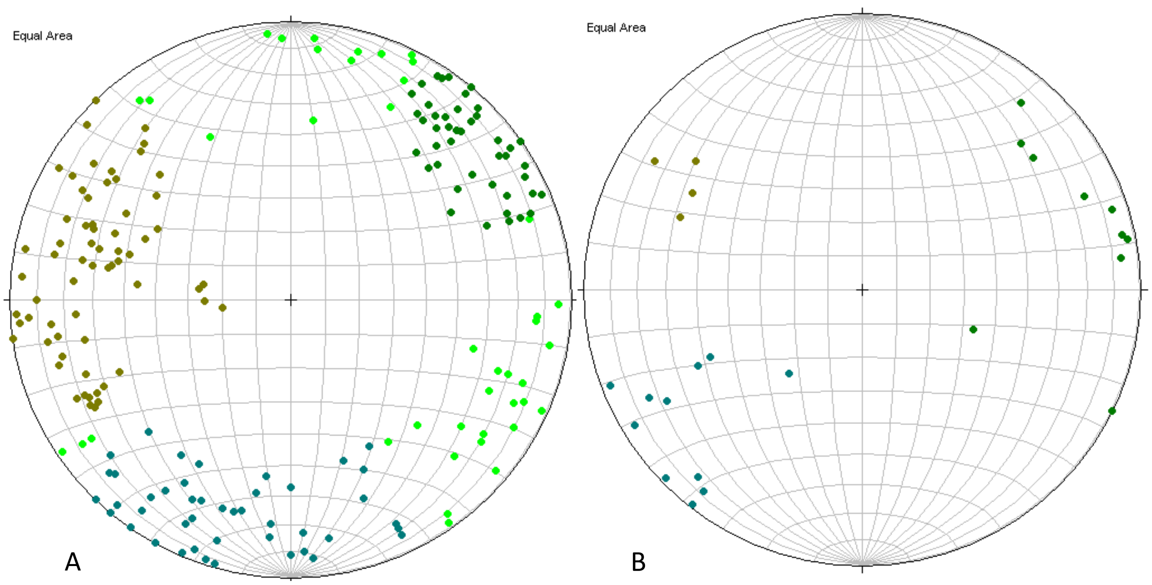


Figure 11: Stereonet plots of all fracture in the cave and surface data sets respectively. A: All fractures measured from the cave. Those measurements not included in a fracture set are light green. B: All fractures measured on the surface. Notice all measurements fit into one of the three designated sets.

Only one stereonet plot was created for faults, combining both those faults measured in the cave and on the surface (Figure 12). Because only two fault measurements were collected from the surface, no meaningful average could be calculated for comparison with the cave data set. Faults generally strike either southeast or northwest. The high concentration of faults dipping northeast (striking northwest) is most likely from the White Formation Passage and surrounding areas where several subparallel fault sets were identified and measured in the cave. The average orientation for all faults is 105.5/52.6 SW.

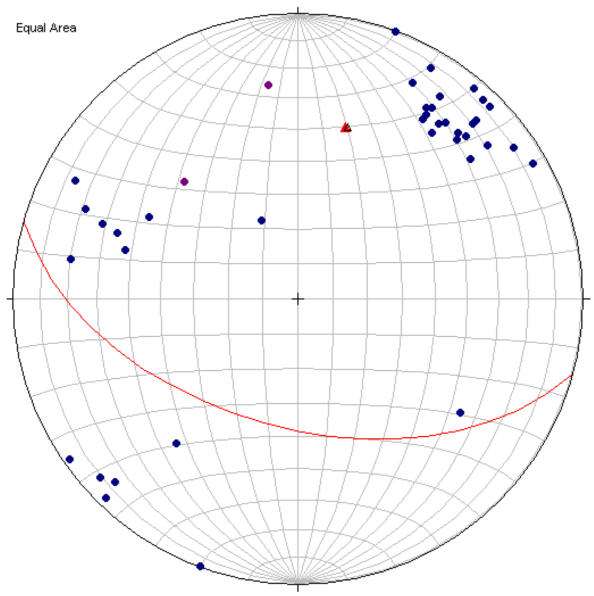
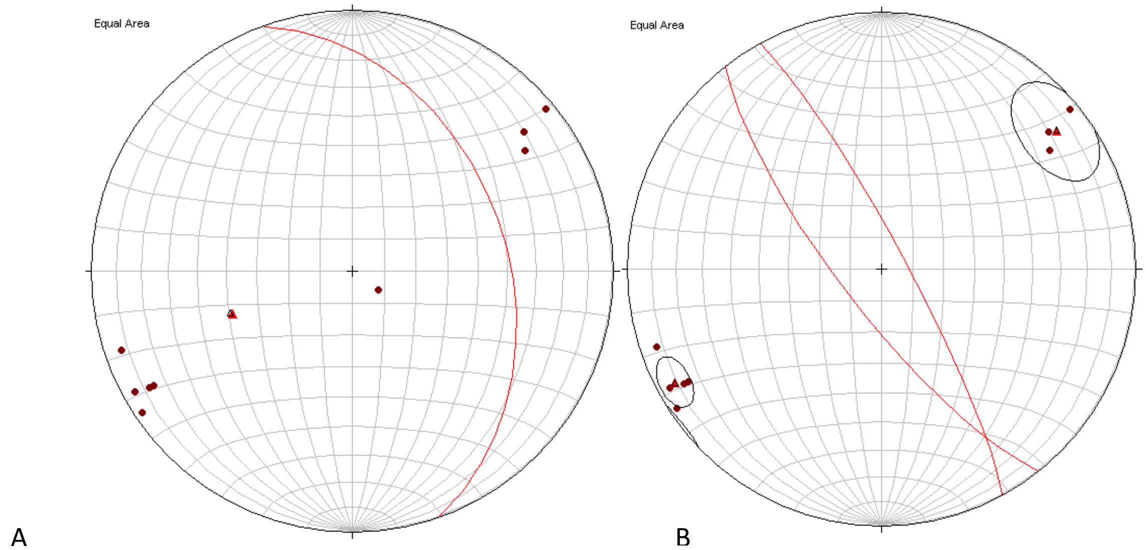


Figure 12: All measured faults with an average orientation of 105.5/52.6 SW. Those measurements from the surface are labeled in light purple.

Though not the primary focus of the study, several dikes in the cave were measured. With the exception of one sill-like structure, the orientations of all the dikes in the cave are remarkably similar with strikes to the northwest or southeast and steep dips (Figure 13). The average orientation, including the sill-like structure, is 340.4/40.4 NE. However, if the one anomalous measurement is removed from the data set, and the remaining measurements are split into two sets, one dipping NE and one dipping SW, then the averages are much more representative of the field measurements. The two calculated average orientations are 142.0/76.7 SW and 331.4/82.1 NE.



(Figure 13): Stereonet diagrams of the dikes measurements from the cave. A: The average orientation including the sill-like structure (circled on diagram) is 340.4/40.4 NE. B: Without the sill-like structure the average orientations are 142.0/76.7 SW and 331.4/82.1 NE.

Interpretations: Passages within Oregon Caves trend both NE and SW, the more dominant of the two being to the NE. Bedding is very uniform throughout the cave, in both strike and dip (36/22.2 SE average) while NE trending passages typically strike between 10 and 40 degrees. The variation in the permeability of the marble, notably the chert interbeds, encourages groundwater to locally flow along bedding parallel to strike. Calcite reacts with carbonic acid where chert does not and as a result chert interbeds can then limit the extent of passage growth forcing groundwater laterally along strike. This interplay between bedding and fractures can be seen along the tour route in the Wind Tunnel, the passage between Miller's Chapel and the Ghost Room, and the South Canyon Passage. At these and other locations, chert interbeds protrude from the walls of the passage and are cut by a fracture running sub-parallel to the strike of bedding (Figure 14).

The other orientation of passageways matches the dominant strike of both faults and fractures within the cave, especially when related to the dominant set of faults within the White Formation Passage. The strongest orientation of fractures and faults lies between 120 and 150, with SE striking passages oriented between 130 and 170. These fractures and faults provide pathways for water to carve out passages perpendicular to the strike of bedding. Looking a two-dimensional map of the cave, the general trend of the cave as a whole is to the NE/SW with smaller passages trending NW/SE seemingly linking the passages together.

A joint set also trends NNE, loosely grouped into a fracture set with strikes ranging from 330 to 50 degrees. This set likely influences the average passage orientation, giving it a more northerly strike than bedding alone. Fractures occurring parallel to the strike of bedding give water that is already flowing between bedding planes a place to drop below less permeable chert beds and access more easily-weathered calcite. It is likely that the bulk of passages within Oregon Caves were created by interplay of both bedding and the major fracture systems.

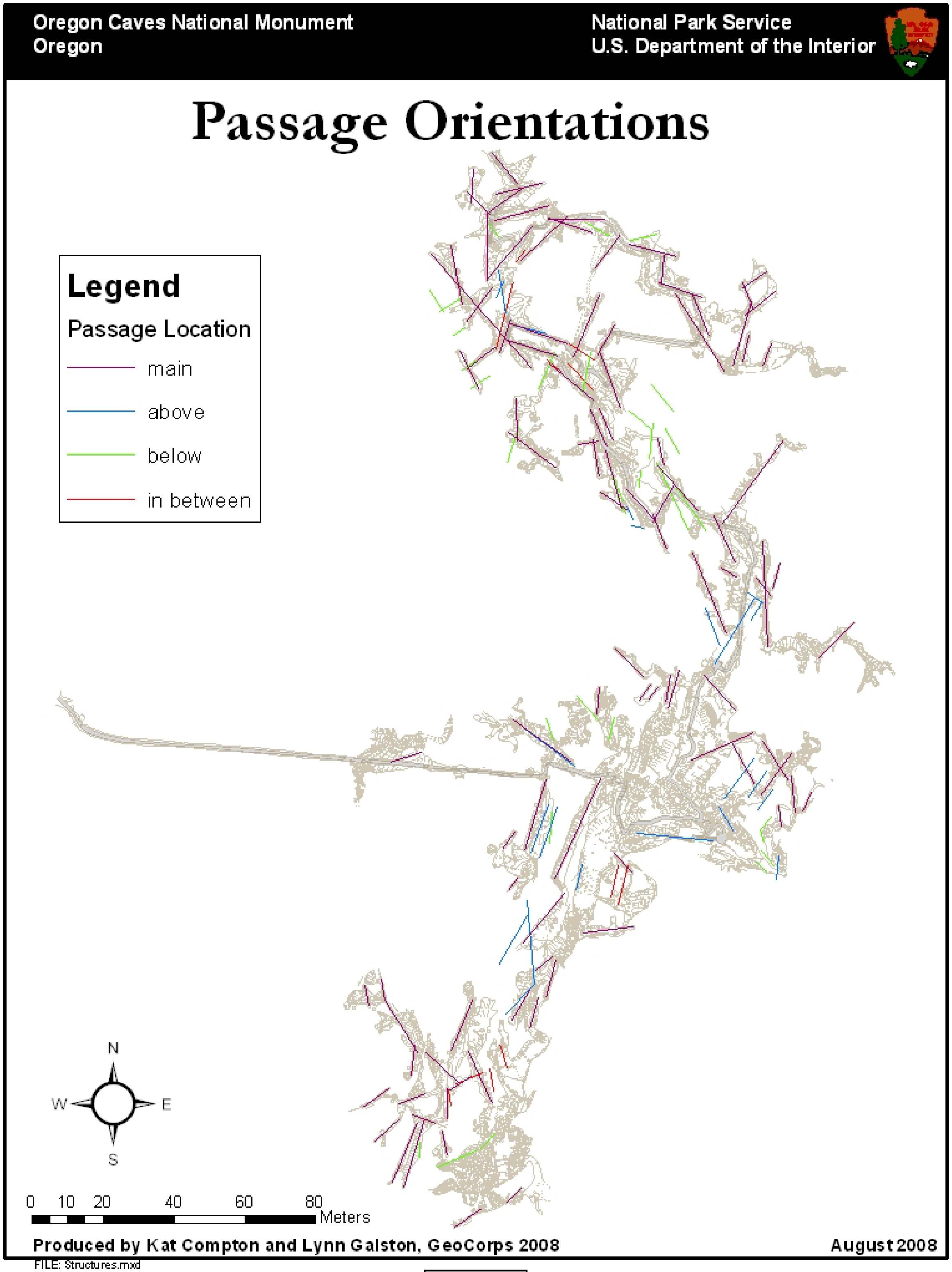
Of the dikes measured, all strike to the NW/SE. These steeply dipping features roughly follow orientations of two fracture sets. Whatever the nature of these dikes may be, it appears that they utilized pre-existing weaknesses in the rock during their emplacement (Figure 15).

Figure 14: Looking south along the South Canyon Passage. Bedding distinguished by the more resistant chert interbeds dips approximately 23 degrees to the east. The interaction between bedding and a large fracture with a strike of 10 (subparallel to the strike of bedding) is most likely responsible for passage formation in this location.

Figure 15: The dikes in Oregon Caves, like this one protruding from the marble in the Ghost Room almost certainly were emplaced along preexisting planes of weakness.

Conclusions: This study was conducted to analyze the effects various structural elements had on passage formation within Oregon Caves. Through the measurement of faults, fractures, and bedding and subsequent plotting of those structures on maps, stereonets, and rose diagrams several conclusions have been made. Passage formation appears to be the result of bedding orientation as well as the fractures which cross-cut those planes. Weaknesses along NE striking bedding planes were further exploited by fractures, while faults and fractures perpendicular to the strike of bedding planes allowed carbonic acid to reach fresh calcite and erode passages to the NW and SE.

The role of dikes is still largely unknown, much less their origin. A petrologic study of these features would greatly increase knowledge of the tectonic history of the cave, as well as improve monument interpretive programs.



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U.S. Department of the Interior
Passage Orientations
Legend
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0 10 20 40 60 80
Meters
Produced by Kat Compton and Lynn Galston, GeoCorps 2008
August 2008
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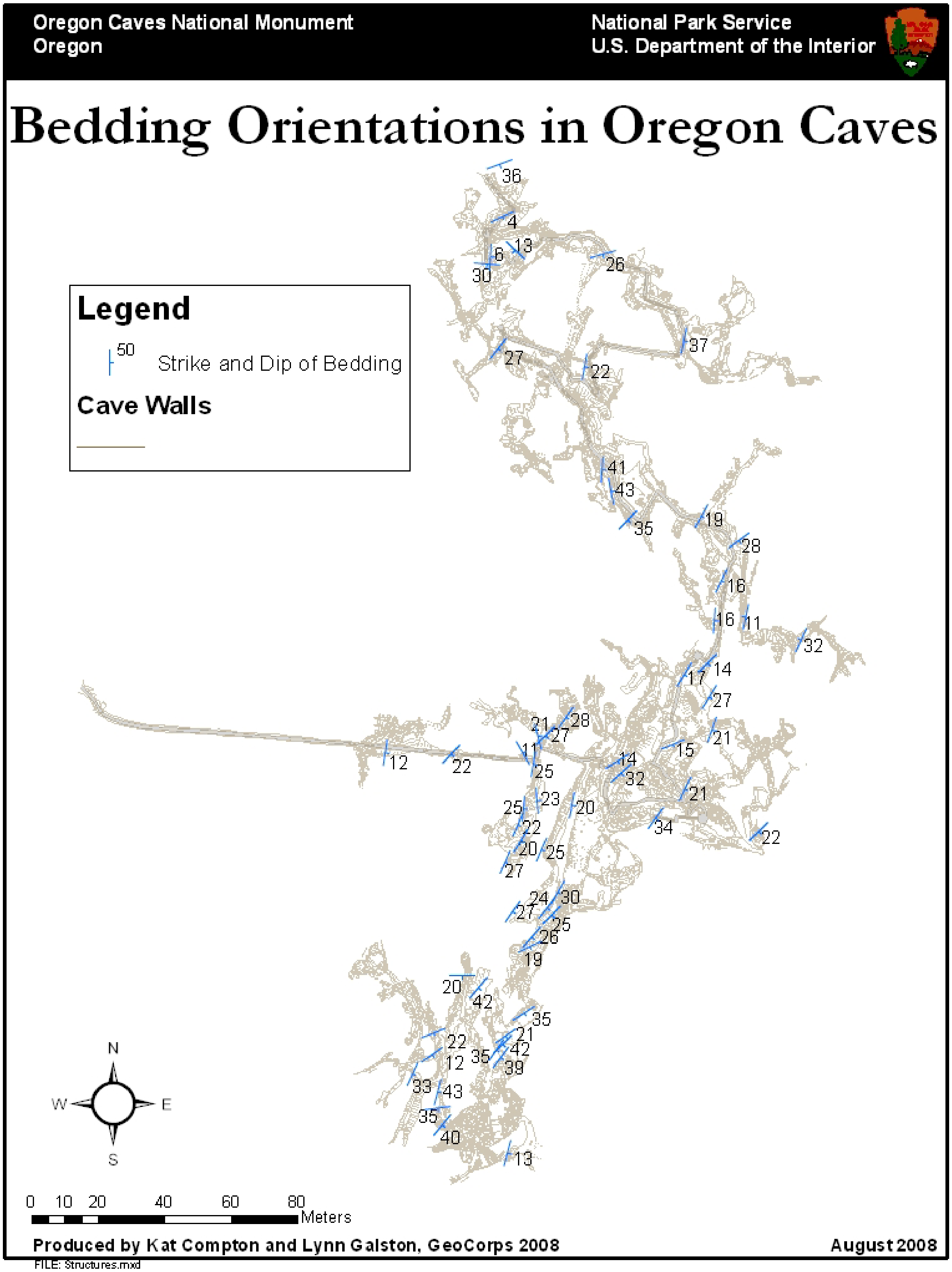
Plate 1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Bedding Orientations in Oregon Caves
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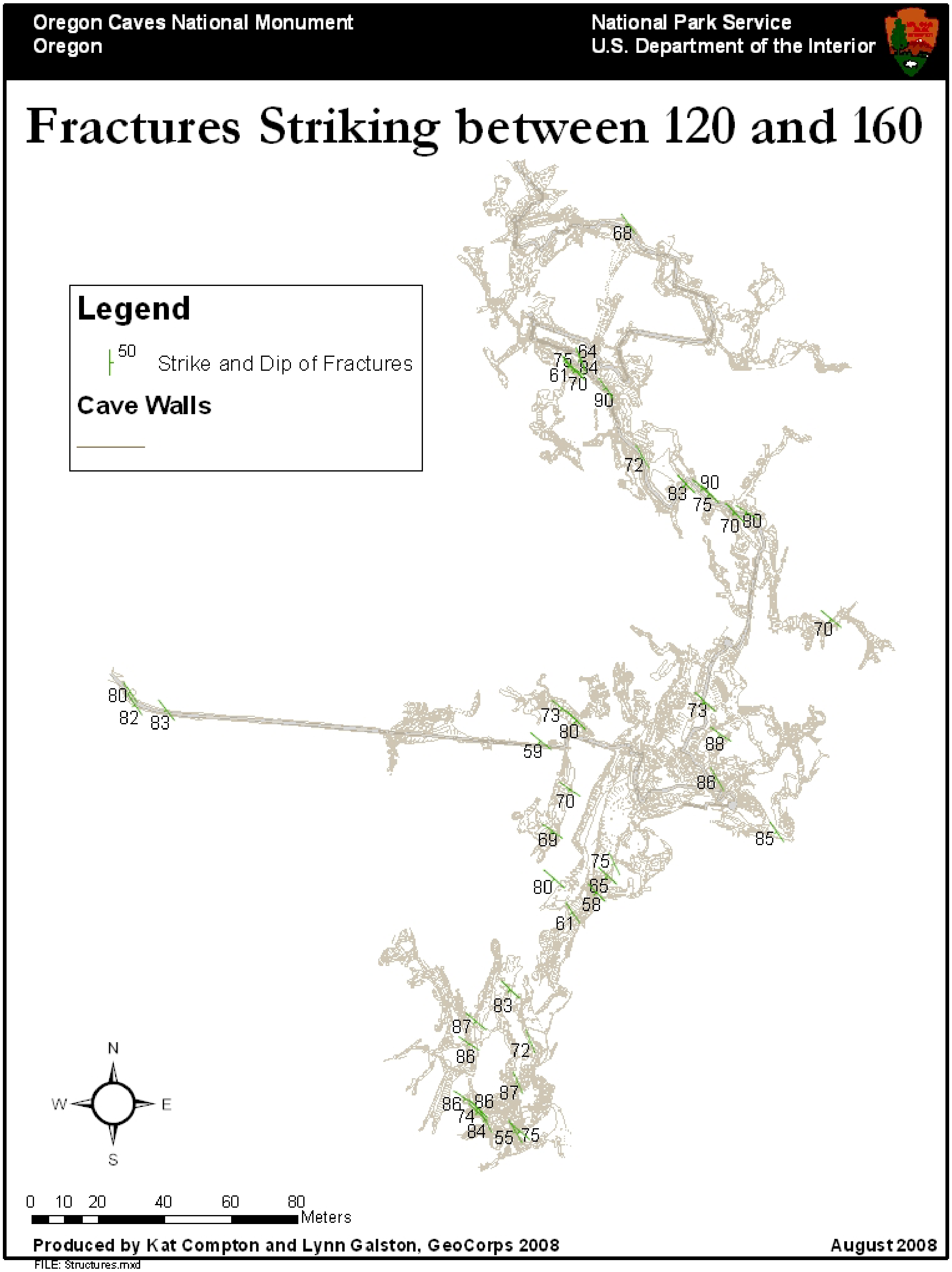
Plate 2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Fractures Striking between 120 and 160
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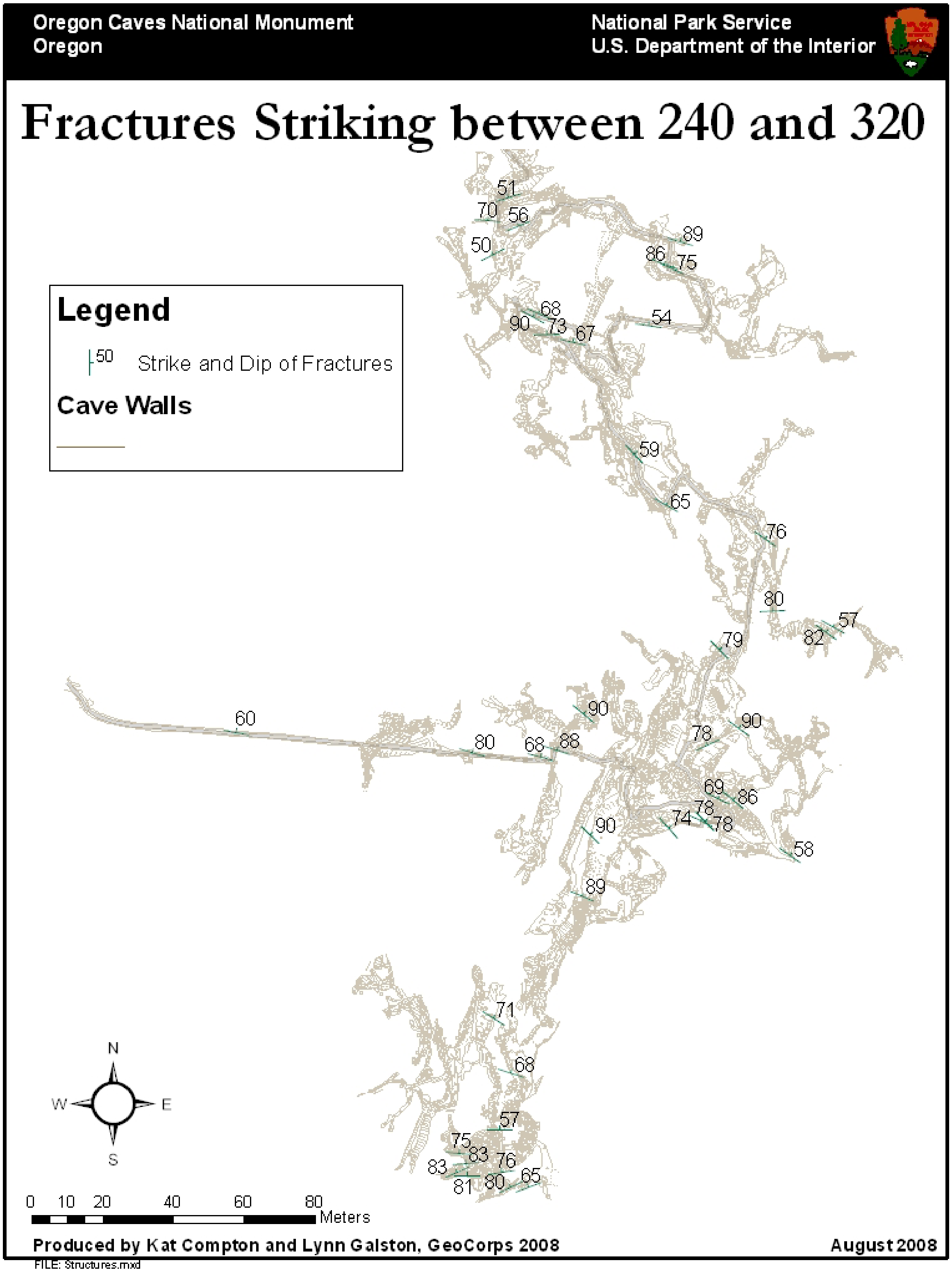
Plate 3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Fractures Striking between 240 and 320
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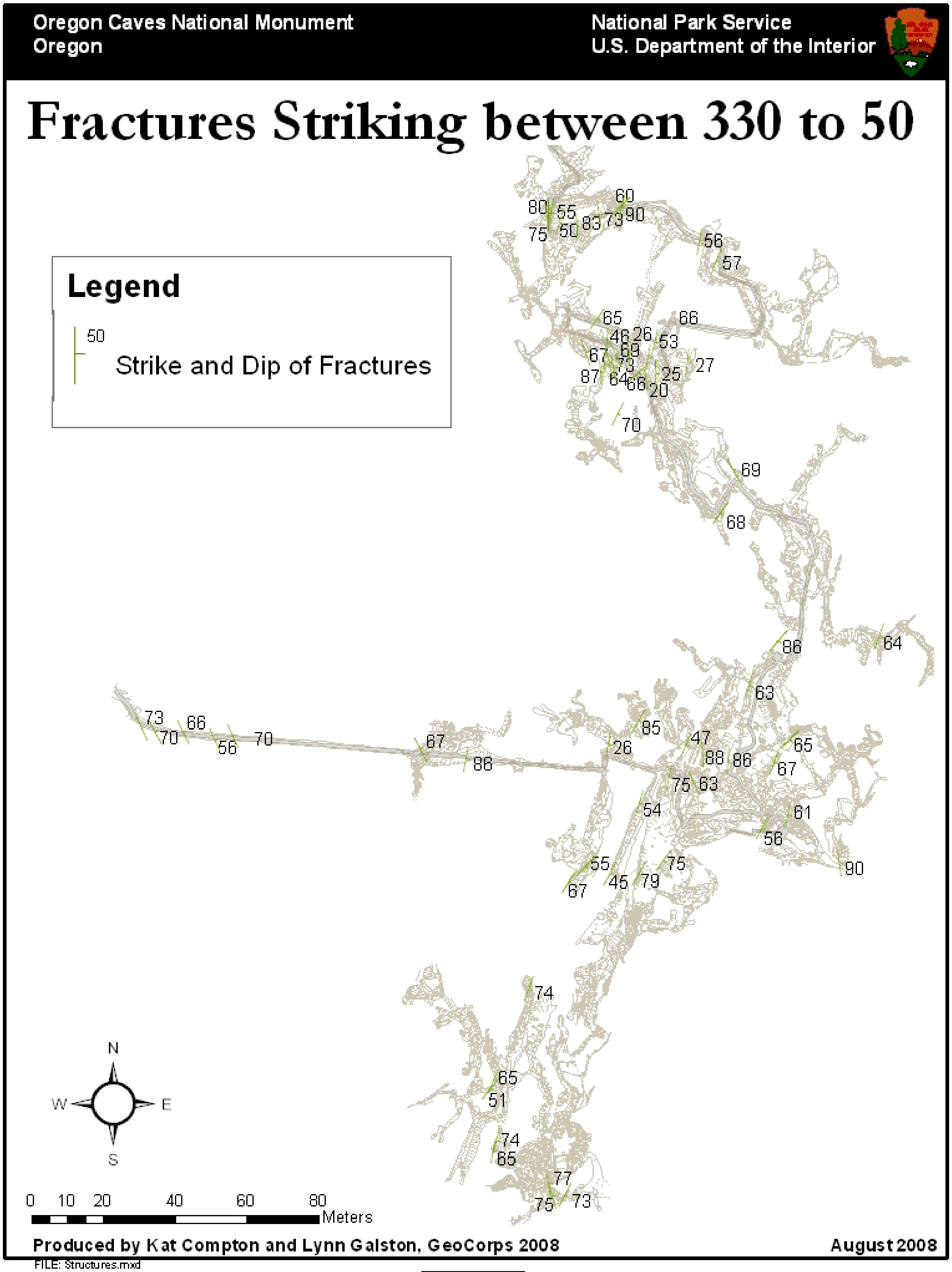
Plate 4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Fractures Striking between 330 to 50
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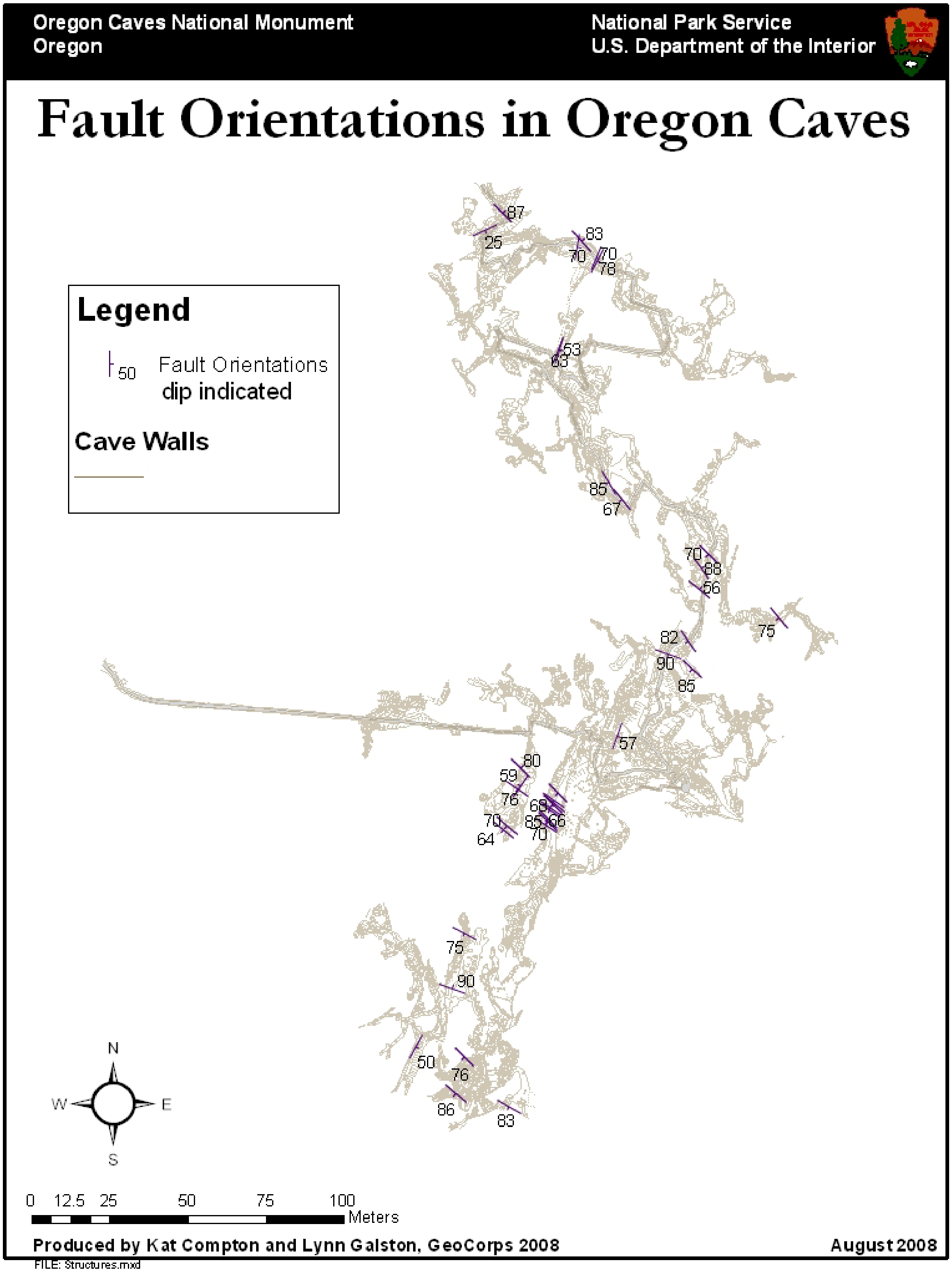
Plate 5


Oregon Caves National Monument
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National Park Service
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Fault Orientations in Oregon Caves
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50 Fault Orientations
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Plate 6

Cave Inventory Glossary: Definitions and Images

1. **Station Number:** Unique alphanumeric identification tag.
2. **Cave Zone (L, M, G, S): L=**Lower: Between the entrance and the 110 **M=**Middle: From the 110 to the Ghost Room **G=** Ghost Room area **S=**South end: South of Kincaid's Dance Hall
3. **Canopies (#):** Flowstone layers that extend out over open space. Most canopies in Oregon Caves form on sediment that later washed away (clastic canopy). Some may have formed on ice during the Ice Ages. A baldacchino canopy is one formed when downward growing flowstone meets a water surface.
4. **Cave Pearls (#):** A smooth polished and roundish concretion of calcium carbonate found in and around shallow holes in cave floors, generally into which water drips.
5. **Column (#):** A speloethem formed by the joining of a stalactite with its counterpart stalagmite.


6. **Conulites (#):** Cone-shaped deposits that line the walls of drip holes in sediment. Partial removal of the sediment at a later time can cause the conulites to stand in relief like empty ice-cream cones.

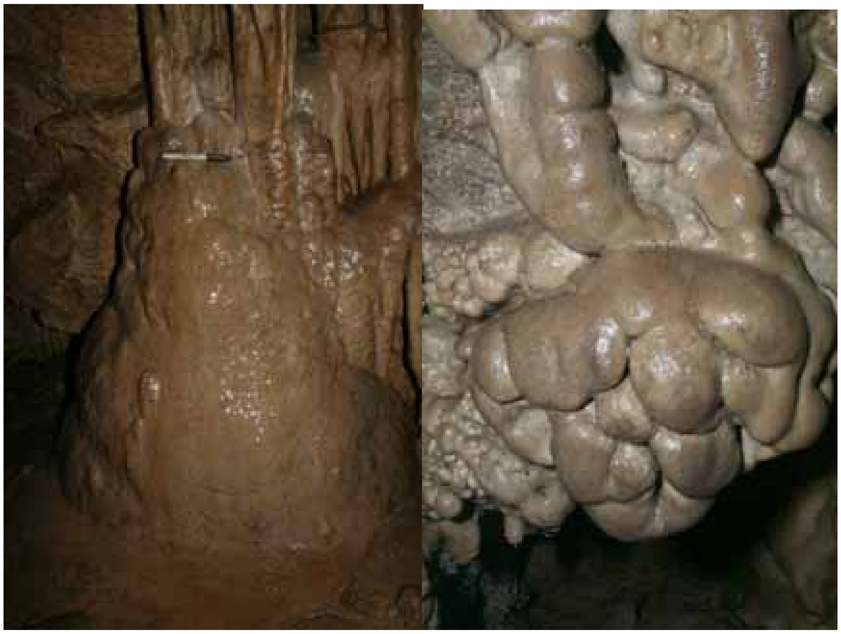
Coralloid: A speleothem type that is nodular, globular, botryoidal, or coral-like in shape and which forms from thin films of water. Cave popcorn is a rounded, microcrystalline coralloid that forms above the water saturated zone. Subaqueous coralloids form underwater but are not common in Oregon Caves.

7. **Superaqueous Coralloid (%):** Coralloids formed above the water saturated zone.
8. **Subaqueous Coralloid (%):** Coralloids formed below the water saturated zone (under standing water).
9. **Coralloid Stem AZM:** Azimuth of growth of coralloid with distinct stem. Use as a proxy for the direction of airflow: measure in the upstream direction. Stems point in the upstream direction.

10. **Coralloid Patch AZM:** Presence of coralloid growth on one side of stone/formation preferentially to the other. Use as a proxy for airflow: measure azimuth in the upstream direction. The side of the stone with the cralloids indicates the upstream direction.
11. **Rimstone Dams (#):** A speloethem type consisting of a barrier of material which obstructs a cave stream or pool. Forms by calcite growth around the overflow edge of a pool.

12. **Microgour Dams (%):** Like miniature rimstone dams. Found on steep flowstone slopes or on the underside of draperies (both in Exit Tunnel) that probably produce frequent and turbulent, but very shallow flows. Microgours don't get large enough to grade into rimstone dams.
13. **Drapery (#):** Curtain-like, linear flowstone from water droplets running down a wall or ceiling. Often wavy or folded. May have a web-like attachment to stalactites**.**


14. **Flowstone (%):** Where water flows in sheets down a surface, depositing calcite. Dogtooth spar crystals - that cannot be seen individually - sometimes impart a soft look to what then is called velvet flowstone.



15. **Exfoliated Flowstone (%):** Flowstone that shows signs of erosion, or broken or peeled-off scales or lamellae as concentric sheets.
16. **White Flowstone (%):** Pure white flowstone. Excludes creamy colors.
17. **Flowstone-Incised Channels (%):** Microkarren composed of dendritic meander karren or microrills from flowing water re-solution.
18. **Flowstone-Pitted (%):** Rounded cavities up to ten cm. across. Often from splashing water on flowstone and also from atmospheric corrosion (deeper, more vertical pits) or from other solution on bedrock.
19. **Flowstone-Pitting AZM:** Azimuth of the pitting if pitting is present on one side of the formation preferentially over the other. Use as a proxy for airflow direction.
20. **Flowstone-Upslope AZM:** Azimuth of the upslope direction of the flowstone as a proxy for the flow of water down the flowstone: measure the upstream direction.

Moonmilk: A speleothem type consisting of white, finely crystalline clay that feels like powder when dry and cream cheese when moist. May result in Oregon Caves from organic activity such as from bacterium actinomycetes, and less often or likely, fungi or algae.

21. **Moonmilk-Soft (%):** Active colonies of moonmilk.
22. **Moonmilk-Hard (%):** Remains of moonmilk colonies no longer active (ex: Imagination Room formations).


23. Shelfstone (%): A horizontally projecting speleothem ledge attached to the edge of a past or present pool. Top of shelfstone may be at the highest water level while the bottom may be the lowest water level.

24. Soda Straw (%): A type of stalactite that at least initially is hollow, and is always tubular. The hollow center is the diameter of the size of the water droplet passing through it.


25. Broken Formations-Loose (#): Broken speleothems present loose on the floor or on a ledge.

26. **Broken Formations-Cemented (#):** Broken speleothems present on the floor or ledge that have been cemented in place by calcite precipitation.
27. **Stalactites (#):** Usually cylindrical dripstone deposits on ceilings. They generally taper downwards due to longer periods of deposition higher up on the stalactite.
28. **Stalagmites (#):** A mounded accumulation of calcite formed by water dripping on the cave floor or ledge: Usually fed by the same water that forms stalactites.

29. **Crystal-lined Pools (#):** Pools of standing water lined with subaqueous crystals visible to unaided eye.

30. **Superaqueous Crystals (%):** Calcite crystals growing above the water saturated zone.

31. **Helictites (#):** A speleothem that twists and branches in an erratic manner seemingly without regard for gravity. Helictites have narrow central canals that feed capillary water to the growing tips.

32. **Construction Rubble (A):** Rubble on which over 50% of the surface is clean, fresh and angular indicating human influence in breaking the marble.
33. **Tour Trail Miscellaneous (A):** Anything that is not covered by another category. Includes steps, pavement, electrical systems, rock walls, etc.

34. **Arches (#):** A residual portion of the roof of a subsurface karst cavity that has not collapsed. Such a natural arch may occur as a surface topopgraphic feature (most often formed underground), or as a part of a cave system.
35. **Bevels (#):** Horizontal channels with indentation more than 3" high in walls. Develop where vadose standing water with an open air surface absorbs carbon dioxide and therefore corrodes faster than water further below. More often formed by running water eroding sideways while flowing on top of sediments.

Boxwork - When palettes intersect from at least three directions. Apparently most common near faults at Oregon Caves. Like the white lines on the "marble ceiling", calcite filled cracks in the marble - creating the boxwork there.

36. **Boxwork-Non Joint (#):**Boxwork clearly not controlled by jointing. No pattern is present and boxwork is anastamosing.
37. **Boxwork-Joint (#):** Boxwork clearly controlled by a joint set, intersecting usually at 120-60 degree angles (sometime 90 degree intersections present as well).

38. **Corrosion (%):** Erosion where rocks & soil are removed or worn away by natural chemical processes. Incl. alluvial, condensation, karst & karren.



39. **Dome/Pit-Fluted (#):** Deep dome or shaft intersected by more or less horizontal passage, characterized by a dome-like top, vertical solution grooves & usually by showering water. Generally circular or oblong in plan view. Fluting - The process of forming a flute by the cutting or scouring action of a current of water flowing over a muddy surface. 2. Scalloped or rippled rock surfaces.
40. **Dome-Smooth (#):** No flutting present in the dome.
41. **Hoodoos (#):** Sediment structure of spires usually in an area of sporadic heavy rainfall or drips by differential weathering or erosion of horizontal strata. Incl. cemented & earth pillar (earth finger & rain pillar).
42. **Meanders (#):** Overdeveloped or self-exaggerated bend in a stream course or other channel either on the surface or underground, caused by more erosion on the outside than on the inside of a bend through natural wash of the flow. Commonly originate in caves as half-tubes along bedding-planes during protocave development.
43. **Pendants/Anastomoses (#):** Vertical (90 to 45^{o}) petromorph projecting from a ceiling. Vertical section is >3 times longer than thickest dimension. Typically 10cm to 1 meter long. **anastomose pendant** – Those formed by anastomoses. In cross-section they often appear as small, inverted flat-topped mesas with rounded edges. (Anastomoses: A braided network of curvilinear, irregular, braided tubes usually from 5-20 centimeter, usually circular or elliptical in cross section. Commonly planar along low dip bedding planes or fractures but rarely big enough to be a cave.)

44. **Pillars (#):** 1. Vertical speleogen connecting floor & ceiling & not wider than the combined width of the two passages it separates. Syn: mitertite. Cf. partition. 2. Remnant of bedrock joining the cave floor and ceiling. Can be formed either by solution or by other processes, as in breakdown.
45. **Potholes (#):** Sharp-edged, rounded basins on the stream or river floor of soluble rocks both underground and on the surface. Trapped clastics enlarge potholes by powdering bedrock and thereby eroding particles and increasing the solubility of what remains. About 20-200 cm wide and deep.

Rill: A narrow groove up to 50 cm from dissolved or eroded in a sloping bedrock or sediment surface by a small stream of flowing water. Rills are usually vertical and perpendicular to the passageway.

46. **Rills-Joint (#):** Rills controlled by jointing.
47. **Rills-Non Joint (#):** Rills controlled only by the orientation of the passageway.
48. **Scallops (%):** Asymmetrical hollows dissolved in a bedrock surface by turbulent water flow. The steep sides of the hollows indicate the direction of water flow. The velocity of the flow that forms them is inversely proportional to the scallop length.

49. **Scallops-Upstream AZM:** The azimuth (compass bearing) of the scallops indicating the upstream direction of water flow.
50. **Airflow-Upstream AZM:** Azimuth (compass bearing) of the direction from which air is flowing.
51. **X-Section Breakdown (A):** Angular cave detritus > 10 cm. wide fallen into a cave room. Incl. block (ceiling, wall), chip, chockstone, congelifract, loose, rafted, room, slab (ceiling, wall), solid.

52. **X-Section Canyon (A):** Steep-walled channel, gorge, or ravine cut by running water.
53. **X-Section Manmade (A):** Manmade alterations ie. paths
54. **X-Section Tabular (A):** Passageways controlled by bedding partings ex: White Formation Passage
55. **Clay Film (%):** Clay film produces a clay stain if touched by dry cloth.
56. **Clay Worm-Complex (%):** Each vermiculation averages at least two sharp angles

57. **Clay Worm-Long (%):** > 3 times longer than broad. Usually horizontal.
58. **Clay Worm-Round (%):** Vermiculation with rounded shape. Often greasy feeling.
59. **Clay Worm-Hard (A):** Vermiculations that have been cemented with calcite

Fill: cave clastic sediment. Unconsolidated, transported deposits flooring or filling a cave passage.

60. **Fill-Clay (%):** Clay that fills or almost fills a cave passage. Clay particles are less than .004mm and feel smooth in teeth or between fingers.
61. **Fill-Silt (%):** Sediment with most particles between 1/16 & 1/256 millimeters or .0625- .004mm. Feels gritty in teeth or between fingers.
62. **Fill-Gravel (%):** Rounded (usually by water) clasts; size of most particles > 2mm or 1/12".
63. **Fill-Breakdown (%):** Angular cave detritus > 10 cm. wide fallen into a cave room. Incl. block (ceiling, wall), chip, chockstone, congelifract, loose, rafted, room, slab (ceiling, wall), solid.
64. **Fill-Flowstone (%):** Passages that have filled in with flowstone.
65. **Fill-Cemented Clastic (%):** Detritus fill has been cemented by calcite precipitation.
66. **Fill-Differentiated (A):** Distinct layering or sedimentary structures such as imbrications are visible in the fill.
67. **Fill-Upstream AZM:** If the differentiated fill includes structures that indicate the direction of water flow, measure the azimuth of the upstream direction.
68. **Dikes-Breccia (#):** Dikes composed of breccia, defined as a coarse-grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or in a fine-grained matrix.

69. Dikes-Quartz (#): Fractures in the marble subsequently in-filled with quartz.

70. Fault Offset (A): Visible offset along a fault plane (ex: offset chert beds).
71. Fault Dip: The inclination (degrees from horizontal) and direction of tilt of the fault plane.
72. Fault Strike: Compass bearing of the line representing the intersection of the fault plane with the horizontal. Usually best to measure the strike using right-hand-rule: record the compass bearing of the strike so that the plane dips to the right.
73. Interbeds-Ash/Argillite (#): Planar layers of ash or argillite approximately parallel to the cave bedding orientation.
74. Interbeds-Chert (#): Planar layers of chert approximately parallel to the cave bedding orientation. Chert beds are often visible jutting out of the walls due to the fact they are more resistant to erosion than calcite.
75. Jointing Visible (#): Fractures in the bedrock with no visible shift or displacement along the plane.


76. **Air-Smoke Moves (A):** Airflow is strong enough to carry smoke.
77. **Air-Feel on Face (A):** Airflow is strong enough to physically feel.
78. **Air-Flame Wavers (A):** Airflow is strong enough to make a flame waver.
79. **Air-Flame Goes Out (A):** Airflow is strong enough to blow out a flame.
80. **Drip-Slow (A):** Dripping water is slower than one drip per 10 seconds per square foot.
81. **Drip-Fast (A):** Dripping water is faster than one drip per 10 seconds per square foot.
82. **Moist (A):** Water present on the cave walls and formations.
83. **Pooled Water (A):** Pools of standing water present.


84. **Stream (A):** Water flow confined in channels. Includes brooks, rivulets, runnels, creeks, & rivers.
85. **Maximum Passage Height in Feet:** Measurement in feet from floor to ceiling along a vertical line.
86. **Bats (#):** Number of bats visible.
87. **Bug Sites (#):** Insect sampling stations.
88. **Cave Slime (#):** Lichen-like white dots.
89. **Rodent Trails or Feces (#):** Slight lines (pathways) or dark patina
90. **Bones-Free (#):** Bones lying free on the surface.

91. **Bones-Buried (#):** Bones visible but only retrievable through excavation.

92. **Snail Shells (#):** Number of snail shell visible at each inventory location.
93. **Arrows (#):** Black carbide arrows burned onto the walls and ceilings of the cave.

94. **Artifacts (#):** Anything human created (does not include arrows, writing, survey markers, or trash). Includes remnants from the abandoned section of trail.
95. **Writing (#):** Number of signatures/other writing on flowstone and other formations. Writing can either be pencil markings or scratches in the formations.

96. Breakage (#): Number of broken formations.

97. Healing (A): Regrowth present on previously broken formations.

98. Healing Length (#): Length of regrowth.

99. Potential for Breakage (A): Soda straws within 6ft: can someone reach or climb to a position to break a formation? Fragility index form the fragility/hazards mapping project.

100. Trash: Current human material of no current use but not a structure. Most common litter in show caves is gum, kleenex, & photographic trash. Can be historic.

Symbol Guide:

A: Yes (1)/ No(0)

#: 0, 1, 3, or 9

- **0: Not present**
- **1: Single item present**
- **3: Several items present**
- **9: Numerous items present**

%: Up to 10, 30, 60, 100%