Dating rock art: two new methods for pictographs and petroglyphs

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Introduction

Rock art is on walls, boulders and bedrock, the last being petroforms or stone alignments depicting animals and other things. Wall and boulder art includes pictographs or painted rock, petroglyphs or engraved rock, or their combination. 20th century archaeologists and rock art historians focused on pictographs because of their colour and possible stylistic dating. Besides style, seven other mostly unsuccessful dating methods existed 40 years ago. They include stratigraphy, superposition, erosion, lichenometry, ethnohistory, prehistory and some laboratory methods. Several are modified for use today. Stratigraphically, most wall motifs do not have buried ivory, bone or wood art that resembles the motifs suitable for cross-dating. Superimposed art determines sequence, not date. Erosion is of limited use, as weathering varies with location, microclimate and rock resistance. Sandstone and other sedimentary rocks erode easily and are poor for dating. Lichen growth, typically of *Rhizocarpon geographicum*, starts any time after the art, its diameter growing only roughly proportional with time. Measuring the largest lichen thallus only gives its maximum age, not that of the art.

Estimating rock art age likely started when art began, when ancient people puzzled over their ancestor's art, trying to answer when and why it was done. Why may remain unanswerable, but it was the earliest form of recorded communication. Tribes now create art for very different reasons than their ancestors, so our interpretive options are not good, especially as art may differ even between tribe members. Many specialists believe rock art was also symbolic, conveying messages, events and stories via symbols and animal and human images. It may also denote ownership, caution, signatures, catchwords, boundaries and tribute. As to when art began, defective dating offers no time-line needed for regional comparison. Most art is dated stylistically because other methods are invasive, require science training or are costly.

Reliable but costly lab methods for identifying or dating pigment and its binders are accelerator mass spectrometry (AMS), spectroscopy, amino-acid analysis, scattered electron microscopy (SEM) and chromatography. AMS dating of an organic pigment binder is promising, but sap binders may be contaminated by dead carbon brought up from the soil in soluble form. This occurs when cactus sap is used as a paint binder because it contains oxalic acid. Cation leaching, X-ray Fluorescence, varnish micro-lamination, obsidian hydration and thermo-luminescence are differential lab methods with a precision of only ±25 to 30%. Cation dating assumes that the ratio of mobile potassium and calcium ions in desert varnish decreases with time compared to the less mobile titanium. This ratio does not date the art but indicates when the varnish ions were leached. Leaching is affected by soil and moisture, so this method needs calibration for each geographical region. A better field-adapted method is X-ray Fluorescence which measures natural airborne manganese accumulation in desert varnish over time. It also needs regional calibration, plus knowledge of the rock angle. Varnish micro-lamination involves dating microgram quantities of carbon within the varnish. But varnish laminations may be open and discontinuous, their carbon easily contaminated by rain or wind-borne pollen and spores. Obsidian hydration dating (OHD) is indirect, but requires regional calibration due to varying moisture, warmth and obsidian type. It assumes atmospheric water enters the obsidian at a predictable rate. It is very useful if nearby dated obsidian artifacts like projectile points are portrayed in the art. But a stratified site near or even under rock art, and dated by OHD or other methods, may not be associated with the art. Thermo-luminescence dating (TLD) relies on electrons trapped in the rock at higher energy states when the art began. When excited by ionizing infrared light, their energy released as light photons is measured as a function of time. It is susceptible to long-term fluctuations in environmental radiation and moisture. It was used to date Australia's Kakadu pictographs to 50,000 years ago. Here, ground ochre surrounded by sand grains is assumed to have been used in the art.

Another field dating method is measuring the depth and type of erosion, mainly of sedimentary rock. It demands calibration curves for each petroglyph, plus mineral solution rates, as erosion is susceptible to moisture differences. It cannot be used on buried art or that immersed in water. It is optical and thus artistically non-invasive where wear is due to solution or granular exfoliation or their combination, and demands measurement over an extended period by a precise dial gauge. Another promising but rare method is iconographic and functions best on known-age art depicting means of transport like the horse or steamship, weapons like projectile points, and extinct fauna. The last is striking in Australia where archaeologists and palaeontologists believe the oldest is a red ochre Arnhem Land pictograph of 40,000 year-old extinct *Genyornis newtoni* birds. Its emu-like bones occur with artifacts in New South Wales. Some think they were hunted to extinction, their painted details passed down only by seeing the live bird. Paintings of extinct thylacine or Tasmanian tiger, giant echidna and giant kangaroo have also been found. Another test useful to dating Pleistocene art is the time-dependant decay or half-life of uranium to lead on mineral surfaces sealed since their formation. This includes re-deposited cave travertine, but also bone, teeth and maritime carbonates. Uranium dating was used to minimum-date South Australia's Malangine Cave to about 28,000 years.

The most outstanding but slightly damaging method over the past twenty years is the AMS dating of wall art drawn with charcoal. Although its destructiveness is limited to areas outside motifs, such dating is rare because charcoal easily washes off surfaces exposed to weathering. Preserved charcoal art is confined to closed caves or those whose entrances are underwater like Cosquer near Marseilles, France. Cave charcoal may come from long-dead wood, making the art appear older, or from living trees applied over older art, making it appear younger. It may come from smoke, humic acids and air-borne pollen. Art in sealed, difficult to access caves may have other problems. Charcoal in the same area should be dated by different labs because it may differ in age due to reapplication, interaction with the parent rock, sample collection problems, laboratory handling and air or water-borne contamination. The accuracy of Pleistocene radiocarbon dates, a topic of this conference, may also be affected by volcanism, which produces non-radioactive carbon, making samples appear older. Dating is further complicated by ancient and unknown cosmic ray activity affecting the radioactive nitrogen-carbon balance.

My method is non-invasive, simple and field-adapted. I added petroglyphs to my IFRAO dating paper on pictographs because we are having some success in adapting it to petroglyphs. The latter also exceed 90% of worldwide rock art, and almost all are undated. Both methods need underlying soil and have been tested under 16 pictographs and five petroglyphs in eight regions of Canada, Mexico and the United States over the past five years (Fig. 1).

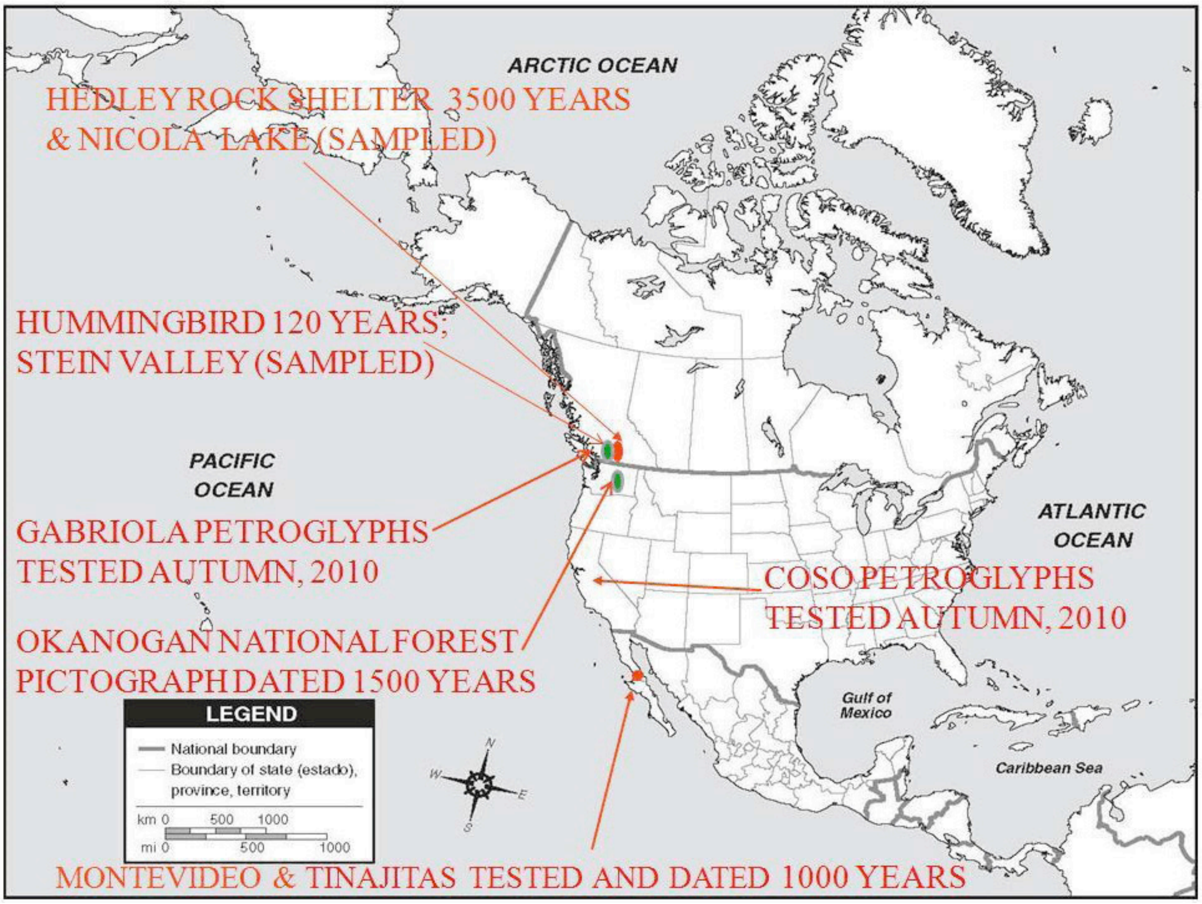

Fig. 1

We tested lab-made rock art before entering the field, easily separating hammer stone chips and rock "flour" created by the hammer stone. These chips differ from natural or flaking debris in being chunky with sharp edges, while the flour differs from fine sand in being flattened. Chips and flour are also whitened from their shattered interior reflective surfaces, proof of the buried floor where a sculptor stood. We used single motifs not palimpsests in the field and avoided desert washes and shore soils altered by wind or water. After my paper I was asked to test in areas away from petroglyphs to see if natural flakes and fine sediment might resemble hammer stone chips and rock flour. I hoped to do this in the Coso National Monument of the China Lake Naval Air Weapons Range, but the US Navy inexplicably chopped our assigned four days to 4-6 hours. I had to postpone this request, but was able to collect soil samples below three petroglyphs. Without this comparison we must assume that most levels are free of hammer stone chips and flour, and that the level with sharp chunky flakes and flattened rock flour is the sculptor's floor. Two Coso motifs appear to be very old double circles and dual spirals, while the third includes a more recent bear paw motif.

Both methods rely on scraping thin levels to sterile soil or bedrock but their analyses differ. For pictographs a water-soluble glue coating on common copy paper applied to the surface of each level removes about 1mm of sediment with possible pigment particles (Fig. 2). The rest is sifted over cardboard in stages, photographed as many times as desired and added to backfill (Fig. 3).

Fig. 2

Fig. 3

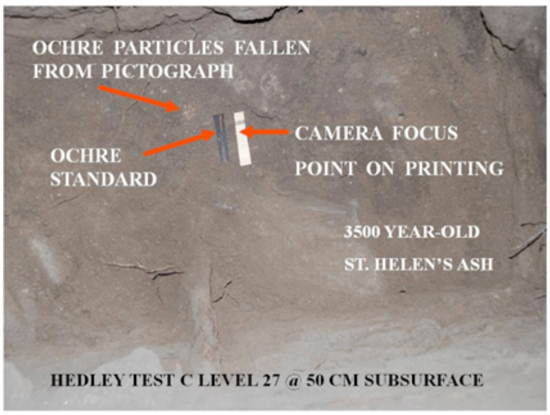

Fig. 4

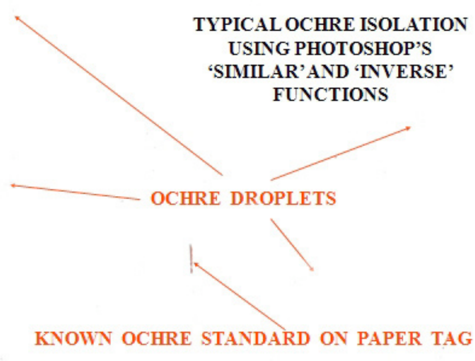

Fig. 5

Particles seen here and on the level photo (Fig. 4) under software enlargement, plus the glue sheet under a stereo-microscope, are summed to give the artistic importance of each level. Many software programs have a similar or inverse function that eases red particle counting by filtering out other colours (Fig. 5). This is especially so on the level photo where we used a red ochre standard on a paper strip to test this function. Glue sheet particles are loosened under a microscope or hand lens with a damp cotton tip, put in gelatine capsules and shipped for SEM identification. Hammer stone chips and pulverized rock flour are sieved from sediment below a petroglyph (Fig. 6). Larger chips and pebbles remain in a 4mm mesh deep fry basket; smaller chips and fine gravel in a nested 1mm mesh kitchen sieve; and sand, silt and flour in an underlying bowl (bottom left). Chunky sharp-edged chips are bagged directly from basket or sieve for washing and examination, as are shell, wood, charcoal, leaf and bone fragments that are removed with tweezers for dating. Pebbles, rootlets and gravel are discarded. If clay clogs the sieve, water immersion lets clay, silt, sand, and flour pass to the bowl. Suspended clay and silt are decanted and the sand-flour sediment separated by even finer sieving. We suspect that sharp chips coated with flour are from hammer stones.

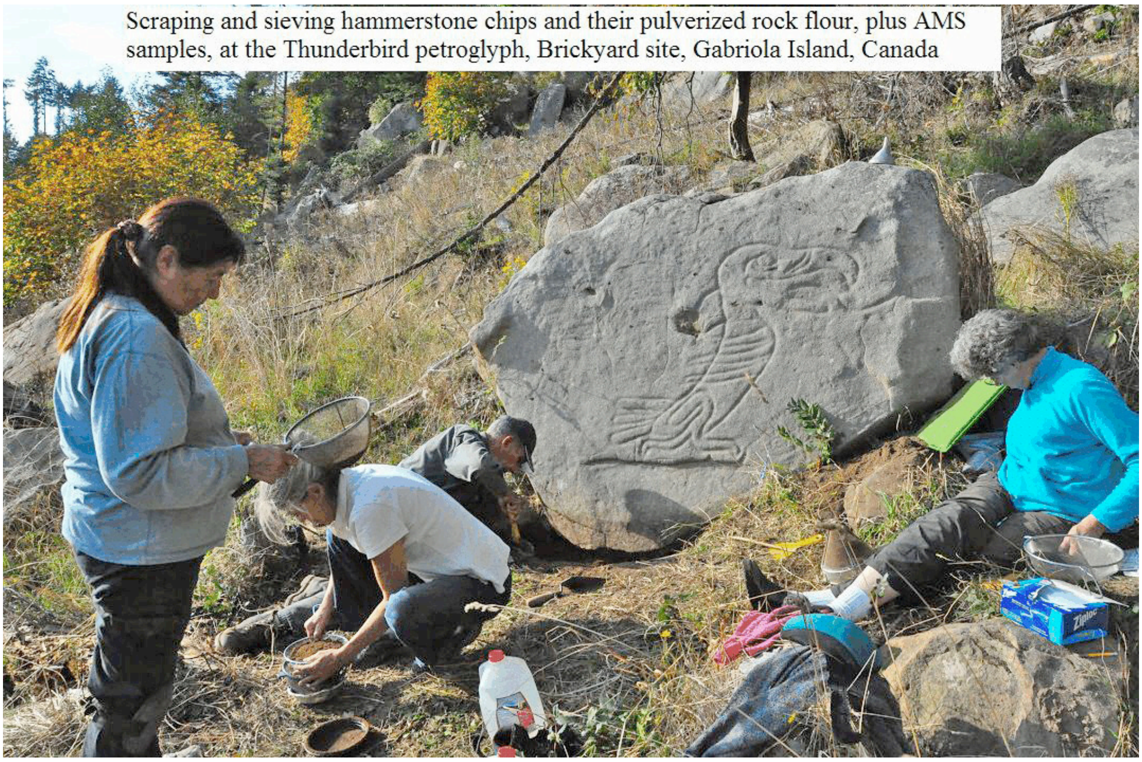

Fig. 6

Rock art specialists need a non-destructive, cheap and simple field method that works for much rock art - caves, boulders and cliff walls, and possibly open-air flat bedrock with nearby soil-filled cavities. But we do need sediment with hammer stone chips and flour or fallen pigment with AMS-datable cultural or non-cultural conifer needles or wood, bone, shell or leaf fragments. To confirm, new tests can be placed alongside existing ones, something we already do if we have sufficient time and crew (Fig. 7). Suspected pigment particles in these tests are identified with SEM to link them to the art (Fig. 8). As worldwide rock art is rarely scientifically dated, our tests may influence its interpretation, especially if we date similar art in one region. Finally, our art is untouched, and each field test requires only a few hours, with follow-up work in the lab.

Fig. 7

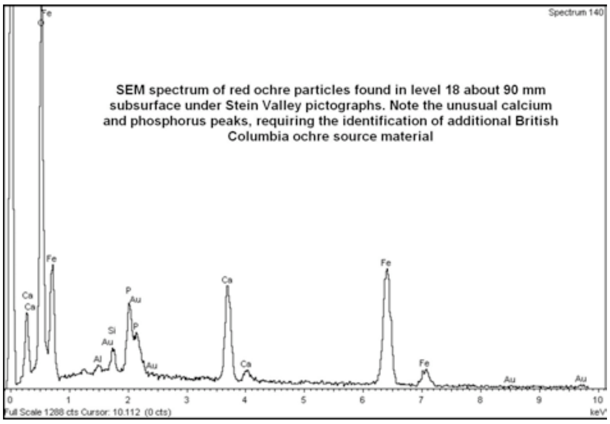

Fig. 8

Assumptions

Fig. 9

All dating methods have assumptions. Pigment or hammer stone chips and rock flour fell below our laboratory-made pictographs or petroglyphs to our feet, so we assume that finding them in soil below rock art represents the artist's floor. This is like chalk dust at a blackboard, droplets while painting, or dust and marble chips in sculpting. Pigment may be residue from a burial or other ritual, but we have never found human bone or painted artifacts. Sharp-edged flakes exist naturally in some soils, but hammer stone chips are chunky and coated with rock flour because they fall together, although most chips scatter. Both methods assume soil levels are parallel to the ground surface, although the artist's floor is disturbed by feet. We found this floor never is a visible band in the soil profile, but we approximate its location by scraping thin layers within a footprint-sized test (Fig. 9). Dating precision rises by scraping thinner levels over tiny areas, but this reduces chances of finding rock art detritus and organic matter together. Compromise is needed. I assume AMS-dated organic matter also dates art debris in close proximity, and that the debris also dates the art. I assume a motif made in a single application has most pigment particles or hammer stone chips and rock flour in one level, and that any multi-level occurrence results from sequential painting or sculpting visits, possibly spanning centuries.

Both methods are artistically non-destructive, quantifiable, repeatable, falsifiable and applicable to cave, boulder and cliff walls and ceilings, and possibly open-air flat bedrock with nearby soil-filled cavities. Neither method touches the art and both are quantifiable, as fallen hammer stone chips, pigment and rock flour are distinct and datable based on proximity to organic material, as in traditional archaeological dating. Both methods are repeatable using nearby tests outside the main particle scatter. Loose particles will later wash down to the rock/soil interface at or above the artist's floor and appear in small numbers in the level analyses. Both methods are falsifiable if pigment or sharp-edged flakes encased in rock flour occur naturally in soil. I assume dating will change our interpretation of rock art by providing a time-line or archaeological phase. This is especially true if a corpus of similarly dated art in one region forms a pattern, an ongoing study (Fig. 10). Testing needs a few hours and even works in clay or damp soil below petroglyphs. I assume wall art is rarely decipherable because the ethnohistory of hunter-gatherers seldom exceeds several centuries. However, records can be very useful in isolated regions where the oral tradition persisted longer.

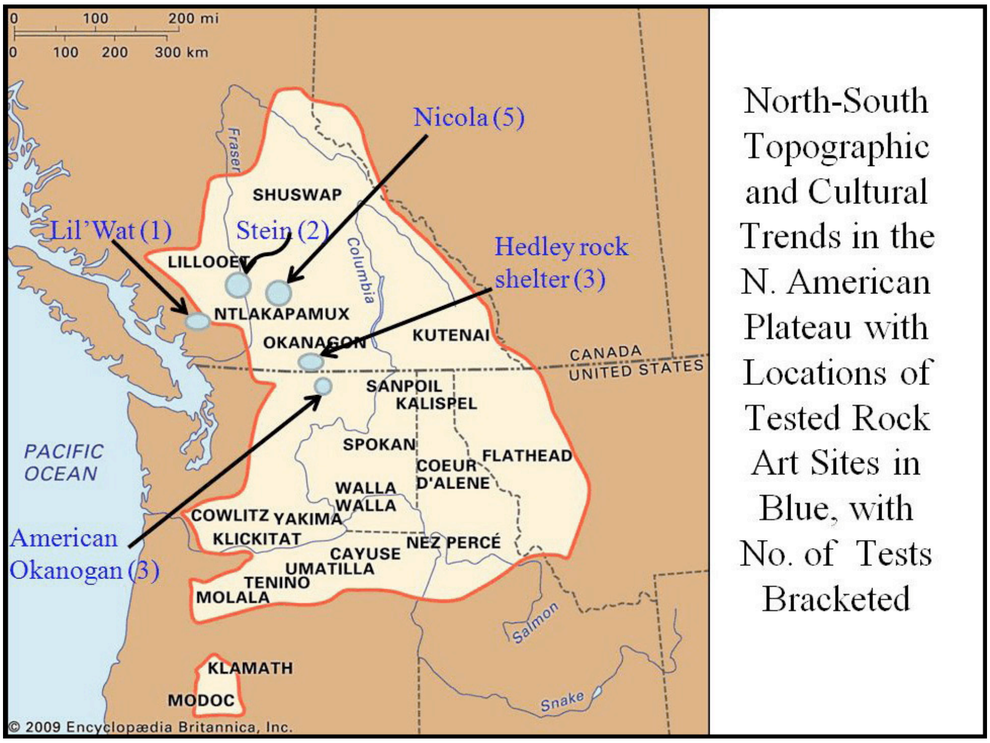

Fig. 10

Technique

Our field tests for dating pictographs and petroglyphs need no formal training, are easy to learn and use readily available material. We drop a pebble from the middle of a motif instead of a plumb bob to find where fallen particles concentrate. To separate fallen debris in petroglyphs we use a kitchen sieve and a fry basket rather than special screens. For pictographs we use glue-coated copy paper instead of adhesive film to trap debris. Of all levels the painter's floor should have more pigment particles on its glue sheet and its surface and sifting photos. The sculptor's floor should have all hammer stone chips and most rock flour. Less pigment or flour in upper or lower levels likely result from later erosion or earlier art, while hammer stone chips are confined to the artist's floor. Chips within flour are a direct link to the petroglyph, while SEM identified particles are direct links to the pictograph. Studies show that a cup of sediment in most levels has enough AMS material for dating.

Field procedure for pictographs

If some feel our field test is complex, a little practice in sterile soil reinforces uniform scraping to a desired thickness over a footprint-sized area. Testing can be done by two people, a pace-setting photographer/scraper and a glue sheet preparer/soil siever. It is better and faster with three –a scraper/glue sheet preparer-drier-stacker, a recorder/photographer with separate tripod-mounted cameras for scraped surfaces and glue sheets, and a siever/AMS sample collector/assistant recorder. Even better, two adjacent tests can be done simultaneously in 6-8 hours by five people, the center person gluing and labelling sheets. We alter our work according to available crew and soil testing difficulties, but do the following:

1. We prefer wall, boulder or ceiling art where paint droplets or pigment fall onto soil. With survey pin, spike, skewer or knitting needle, we probe soil beyond the anticipated 20x30cm test to at least 10cm below any surface litter (Fig. 11). We avoid buried rocks by repositioning our slot.

Fig. 11

2. For vertical and overhanging sides of cave walls, cliffs and boulders, we drop a pebble from the most pronounced motif. Around its impact point we remove enough surface litter and disturbed soil to provide easy access for scraping the slot with its long axis parallel to the wall. For ceiling motifs the size of soil tests should conform to their size.
3. We place a tripod-mounted camera with zoom lens 1.5m above the slot for comfortable access to scraping and glue sheet application. A zoom is best to constantly cover the 20x30cm test as it deepens, but a fixed focus lens (100-150mm according to camera height) can be lowered using the tripod center post to maintain this area. For sifted soil we place another tripod-mounted camera with a fixed lens (height is constant) or zoom capable of including the large piece of cardboard (Fig. 3). We use sunlight whenever possible, moving a tripod leg throughout the day to avoid its shadow in the photo. We use flash in caves, rock

shelters and shaded areas, adding an umbrella or tarp to block changing sunlight in shaded areas.

4. As critical focusing on soil grains is impossible through camera eyepieces, we use a tiny high-contrast yellow tag with black printed level number. We place this on each scraped surface and transfer it for photos of its glue sheet and each sequential sifting. As a glue sheet used for microscopy has no paper tag, its level number and orientation are written at one chosen end for later comparison to its photo.
5. We lightly coat glue sheets with water-soluble glue by running a vertical bead several centimeters from both ends and spreading each to the center with a 5-10cm wide fine brush. After applying firmly to the soil surface, we turn it over for photography, adding the tag. Too little glue creates soil voids on the paper; too much covers particles and leaves glue on the soil. This must be removed to avoid problems with sieving and AMS-dating. We place the glue sheet aside to dry.
6. To minimize soil disturbance we scrape each level in a practiced pull into a dustpan at one end of the slot with a vertically-held mason's trowel. This is transferred to a sieve and partly but evenly sifted onto the cardboard for photos. We maximize particle counts by repetitive sifting and photos, transferring the level tag each time. AMS samples in the sieve are removed with tweezers and wrapped in aluminum foil, adding another fold to attach the tag for confirmation. We write the tag number in felt pen on the foil itself for quick identification. We collect sifted soil in a bucket for backfilling.
7. We scrape 5mm levels to bedrock or sterile soil (10 to >100 levels), collecting soil around buried rocks until their needed removal, which appear as voids in photos and glue sheets.
8. Records are kept by a supervisor or any crew member with free time. The glue sheet stack is dried and shipped compressed to inhibit particle movement and loss.
9. We photograph and assess the rock type, noting loose pigment particles on the art.
10. We backfill the test, then replace surface litter and clear footprints and intrusion signs.
11. We keep separate all camera memory chips and glue paper stacks for each test.
12. We backup memory chips to laptop and/or portable hard drive as soon as possible.

Field procedure for petroglyphs

Again, a little practice in sterile sand enables uniform scraping to possibly larger thicknesses over a footprint-sized area. Testing is best done by 3-4 people, a pace-setting scraper who records findings and helps sieve, and 2-3 sievers who divide level sediment and remove AMS samples with tweezers, and pebbles, big hammer stone chips and rootlets by hand. Labour varies with sieving difficulties posed by soil wetness and clay content.

1. This procedure is similar to pictographs but where hammer stone chips and rock flour fall, rather than paint particles or droplets. Where possible a convex surface can concentrate flying chips and flour to a boulder's base.

2. Like step 2 under pictographs but slots under leaning walls and boulders should be hard against their base to catch any debris line of sliding rock flour. Bedrock or horizontal slab petroglyphs might be dated if hammer stone chips are projected into nearby cavities.
3. We use sieves instead of cameras, beginning with a fry basket to collect AMS samples and hammer stone chips, crush clay lumps and discard rootlets and pebbles.
4. Material passing the basket to the sieve is handled similarly, but damp soil or balled clay that cannot be squeezed through must be washed through and removed by decanting. Small hammer stone chips are added to those from the basket, washed and examined.
5. Repeated decanting results in a slurry of fine sand and possible rock flour. It may be dried for microscopic or hand lens exam, or passed wet through a fine screen.
6. If sieving and screening shows hammer stone chips and rock flour in one level, submit an AMS sample for dating.
7. We backfill the test, then replace surface litter and clear footprints and intrusion signs.

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