Dating of rock paintings in the Americas: A word of caution

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"We do not believe any group of men adequate enough or wise enough to operate without scrutiny or without criticism. […] *Science is not skepticism.* […] *But for scientists it is not only honorable to doubt; it is mandatory to do that when there appears to be evidence in support of the doubt."*
Oppenheimer 1951: 6

"Permit us to question –to doubt– that's all –not to be sure."
Feynmann 1999: 146

Abstract

Rock paintings have been dated for more than two decades. Most of those dates are reliable. Nonetheless, the current situation in the Americas still remains less than ideal. Only one independent analysis on a single pictograph (found under a calcite accretion layer) has been done to compare/verify methods used. And when that was done, agreement was totally lacking. That case will be discussed. Caution is indicated before indiscriminately accepting rock art dates until further independent tests are available.

Dating pictographs in the Americas has become more and more commonplace during the past couple of decades. But in spite of that, the field appears to me to remain scientifically immature. For this research area to become an established science, a number of checks and balances must be introduced and become the norm in dating studies –at least until there is compelling confidence in the dating method being used. That is not the case in many instances at the present time. Rock art experts and archaeologists working with rock art may too readily accept a date provided to them without having any verification of the reliability, accuracy, and validity of the method used. Conversely, they may be inclined to summarily discard a measured date if it does not agree with their preconceived notion as to the age of a given style of pictograph. Although I am speaking only about pictograph dating for the most part, what I say applies to the dating of petroglyphs as well –perhaps even more so.

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How should techniques/measurements be verified?

How can rock art chronographers and their archaeological collaborators know they (we) are getting accurate dates? This is currently a serious problem in rock art dating.

Standards: One time-tested means to verify an experimental technique/ measurement is by comparison of the new measurements with known-value standards to ensure that the technique gets the correct known value. But there is possibly only one American group of known-age rock paintings to use for such standards in the dating of rock paintings: Maya calendar dates written in the rock art at the Guatemalan cave, Naj Tunich. The drawings there have charcoal pigment and suffice to test only the dating of charcoal-pigmented rock paintings, which probably give the most reliable results so far.

Inter-laboratory Comparisons: Another accepted, and normally required, technique used when testing an analytical method is the use of inter-laboratory comparisons. That procedure is used in virtually all scientific analytical studies. Inter-laboratory comparisons are absolutely essential –but they are almost non-existent in American pictograph dating studies– and agreement is sorely lacking. If the science of rock art dating is to thrive, this must change, but I see no evidence for that change occurring presently. I will discuss the one case of an independent, inter-laboratory comparison that we have so far in American pictograph dating studies. Unfortunately, there is total disagreement between the two laboratories involved.

Radiocarbon Standards: In radiocarbon studies, there should also be routine measurements of other radiocarbon standards with *known* radiocarbon content. Again this is a standard procedure in most radiocarbon studies, but it appears to have been rarely used (or at least virtually never reported in publications) in rock art studies. It is also necessary to measure radiocarbon-*free* materials. That is also a standard procedure used in radiocarbon laboratories studying other archaeological artifacts, but is once again rare in rock art studies, unless the chronographers involved take it for granted that such studies are necessary but do not report them.

Archaeological Inferences: Archaeological inferences may be useful in some rock art dating research to verify the technique in cases where the inferences are strong chronologically. That is, one can use archaeology to estimate correct ages in *some* cases. However, it is rare that archaeological inferences give accurate enough ages (or more commonly, *age ranges*) to really adequately *test* a new technique for accuracy and reliability.

Reporting Experimental Procedures: Importantly, researchers should include detailed enough description of procedures in their publications on pictograph dating that other competent scientists can attempt to reproduce their data. In the end, that is how science progresses. Scientist A finds a result. Then scientist B attempts to reproduce the data, ideally using an independent technique with different underlying assumptions, although sometimes using the same procedure. That is often omitted in rock art studies.

Blind Tests: Finally, blind test comparisons between independent laboratories constitute good practice.

In some instances, established radiocarbon laboratories that are involved in dating pictographs, especially charcoal-pigmented ones, *may* use most or possibly even all of these safeguards to ensure that their dates are reliable and accurate. Too often, however, no such verifications are included in pictograph dating publications. Nor are they commonly even referred to. Inclusion of such verification studies would help unbiased readers evaluate a technique used by a given researcher. I have often been asked by archaeologists and rock art experts to give an opinion on chronographer X's work, but I find that most often I cannot give an *informed* opinion because of the lack of experimental detail given in typical publications in the field. This too should change.

Case study: Toca do Serrote da Bastiana, Brazil

Controversy has lingered for over two decades concerning the antiquity of early human presence in Brazil (Guidon & Delibrias 1986; Guidon & Arnaud 1991; Metzler *et al*. 1994; Guidon *et al*. 1996). Guidon & Arnaud (1991:167) wrote over twenty years ago:

"The chronology of the earliest periods of occupation in the New World is a subject of intense controversy. … it is time for the 'cold war' of Americanist archaeology to come to an end; the two camps –those favoring early colonization, and those setting a limit at 12,000-14,000 BP– must seek out in collaboration the evidence for building up a cultural sequence which can be accepted as the only real accurate record of the peopling of the continent."

Unfortunately, that could have been written yesterday, although some progress has been made in the acceptance of earlier peoples than the Clovis culture (Adovasio & Page 2002; Collins *et al.* 1991; Dillehay 2000; Thomas *et al.* 2008; Waters & Stafford 2007; Goeble *et al*. 2008).

Guidon and her co-workers (Guidon & Delibrias 1986; Guidon & Arnaud 1991; Parenti *et al*. 1996; Santas *et al*. 2003; Pessis & Guidon 2009) have long maintained that humans arrived in Brazil >50,000 years ago and certainly before the 12,000-14,000 years BP of the "Clovis First" adherents. The major objection to that work was whether the stone 'artifacts' were altered by natural processes, not by human activity (Borrero 1995; Dennell & Hurcombe 1995; Prous & Fogaça 1999). The experts disagreed. Clearly, that objection is not relevant to considering the age of rock paintings. While charcoal and quartzite flakes found at Pedra Furada could be construed to be of natural origin, rock paintings found nearby cannot be. I want to make it clear that the discrepancy that follows does not pertain to the larger question Guidon and Arnaud posed. I will be only describing a large discrepancy between the dates on calcite and rock paintings.

We are concentrating here only on a painted limestone shelter, Toca do Serrote da Bastiana, although dates on pictographs from that and other nearby sites will be mentioned as they are pertinent to the debate at that site. An age of >35,000 years ago reported in 2003 by Watanabe *et al*. on a rock painting would help resolve the issue in favor of the great antiquity Guidon and her co-workers have posed -- if it were *known* to be correct. Alas, life is not so simple.

The situation at Toca do Serrote da Bastiana in Brazil has been discussed before (Watanabe *et al*. 2003; Steelman *et al.* 2002; Rowe & Steelman 2003; Rowe 2007), but it is worth reiterating the difficulties further. This is a good case of an interdisciplinary, inter-laboratory comparison in which completely independent techniques were compared, but in which there remains a serious, very large discrepancy. The study by Steelman *et al*. (2002) and Rowe & Steelman (2003) did not confirm the age reported by Watanabe *et al.* (2003); it was not even close, not even within an order of magnitude! Resolving this issue is of critical importance because of the exceedingly important archaeological implications of the Watanabe *et al.* ages. We discuss the studies below, but the issue remains totally unresolved. Additional ***independent*** studies are essential in order to resolve the age of the rock painting at Toca do Serrote da Bastiana. The ages obtained so far are discussed below.

Summary of the University of São Paulo results

Methods 1 and 2: Pessis and Guidon (2009) summarized the history of the dating of the Toca da Bastiana site as follows: The first date for a calcite layer covering two anthropomorphic red images (17,000 years ago) was by Oswaldo Baffa of the University of São Paulo using electron paramagnetic resonance (EPR), also called electron spin resonance (ESR). That was followed by two EPR dates by Watanabe of 33,000 and 35,900 years and then, using thermoluminescence (TL) and EPR, two more of 48,286 and 39,442 years were obtained (Pessis & Guidon 2009).

Fig. 1. The red anthropomorphic image on the left was the focus of our radiocarbon project at Toca do Serrote da Bastiana. The calcite layer also discussed is clearly visible on the left side of the figure as viewed, and originally covered the two central motifs.

Watanabe *et al.* (2003) reported dates from two techniques relatively new to rock art dating to determine the age of a calcite (calcium carbonate) layer that formed on top of an iron ocher pigmented red painting at Toca do Serrote da Bastiana near the Capivara National Park, near the town of Sao Raimundo Nonato in Piaui, Brazil. The pictographs and the calcite layer involved are shown in Fig. 1. The techniques used by Watanabe *et al.* were TL and EPR. Unfortunately, Watanabe *et al.* did not include enough experimental detail for the results to be evaluated by an outside expert. Although different, the EPR and TL methods are not truly independent of one another as they are based on essentially the same assumptions. Watanabe *et al*. concluded that the calcite layer was >35,000 years old –and thus the painting underneath would have to be even older than that. The repercussions of such a date are obvious. Clearly the painting was made by a human. Thus this would confirm that human occupation of that area of Brazil would have occurred over 35,000 years ago as argued by Guidon and her co-workers (Guidon & Delibrias 1986; Guidon & Arnaud 1991; Parenti *et al*. 1996; Santas *et al*. 2003; Pessis & Guidon 2009, to list just a few).

Summary of Texas A&M University results

Dr. Niéde Guidon asked if we would attempt to date the calcite layer that occurred o*ver a red painting* –the same calcite layer that was dated by Watanabe *et al.* (2003). Because of the serious implications of the ancient age, we immediately and enthusiastically agreed. Watanabe *et al*. had obtained multiple ESR/TL dates that were in general agreement with each other. Without the Texas A&M University dates (discussion of those follows), one would have most likely readily accepted their very old dates. But, unfortunately, as I said earlier: Alas, life is not so simple.

Method 3 – **radiocarbon date of oxalate in calcite layer**: Our initial approach was to date the calcium oxalate that was admixed in the calcite layer because we knew we could date the carbon in the oxalate by radiocarbon analysis, a well-established technique (Russ *et al.* 1996; Russ *et al.* 1999; Russ *et al*. 2000; Watchman 1993; Watchman & Campbell 1996; Ruiz *et al.* 2006; Ruiz López *et al*. 2009). Furthermore, the assumptions involved in radiocarbon dating of the oxalate in the calcite accretion were totally different from those of TL and EPR used by Watanabe *et al.* (2003). Thus the results constitute an independent approach. Unfortunately, the oxalate accretion admixed in with the calcite layer yielded two radiocarbon dates of 2540 ± 60 years BP and 2470 ± 40 years BP for a weighted average of 2490 ± 30 years BP, over an order of magnitude more recent than the age of Watanabe *et al.* of >35,000 years ago. Our conclusion based on the oxalate dates was that the painting underneath had to have been painted >2490 years BP.

As another piece of evidence favoring the younger date we obtained for the oxalate in the calcite layer, Hassiba *et al.* (2010) have shown that one can estimate the age of the rock painting covered by the calcite (oxalate) layer by making the following assumptions:

1. assume a uniform deposition rate of oxalate layer over time;
2. assume at time $t = 0$ a painting is placed on the rock;
3. assume that the current time $t = T$;
4. assume that the rate of deposition of oxalate is $h(t)$, and the current thickness is H;

5. assume that the oxalate only began to deposit after the wall was painted;
6. assume that the sample taken has a cross section area A;
7. assume that the density of carbon atoms is given by ρ;
8. assume that the decay rate of ^{14}C is λ.

Discrete approximation: Assume a thickness *Δh* is laid down in the first year. The number of ^{14}C atoms is equal to the volume *AΔh* times the density ρ. After a length of time T, with decay rate λ, the number of atoms is $(A\Delta h)\rho e^{-\lambda T}$

The second layer, at *Δt* later, contributes $(A\Delta h)\rho e^{-\lambda(T-\Delta t)}$

And so on. The total number of ^{14}C atoms is given by the summation of the series:

$$(A\Delta h)\rho e^{-\lambda T} + (A\Delta h)\rho e^{-\lambda(T-\Delta t)} + (A\Delta h)\rho e^{-\lambda(T-2\Delta t)} + (A\Delta h)\rho e^{-\lambda(T-3\Delta t)} + \ldots + (A\Delta h)\rho$$

In the limit, this becomes an integral

$$\int_a^T A\rho e^{-k(T-1)}\, dh = \int_a^T A\rho\, e^{-k(T-1)} \frac{dh}{dt}\, dt$$

Assuming a constant rate of deposition, and a final thickness H, then $\frac{dh}{dt} = \frac{H}{T}$ so the integral reduces to

$$A\rho \frac{H}{T}\int_a^T e^{-k(T-1)}\, dt = \frac{V\rho}{T}\int_a^T e^{-k(T-1)}\, dt = \frac{V\rho}{T} e^{-kT}\int_a^T e^{kt}\, dt$$

$$= \frac{V\rho}{T} e^{-kT}\left(\frac{e^{kT}-1}{k}\right) = \frac{V\rho}{kT}\left(1-e^{kT}\right)$$

By way of comparison, a core sample of volume V and age T would have

$$\frac{V\rho}{T} e^{-kT}$$

Figure 2 illustrates the difference between the two functions, e^{-x} on top, and $\frac{1-e^{-x}}{x}$ on bottom. In Fig. 2, the y-axis measures the ratio of the radioactivity of a sample to a sample with modern radiocarbon level (for a given volume). Clearly, given two samples with equal radioactivity on the y-axis − one deposited continuously and one deposited essentially instantaneously after the painting was formed − the radiocarbon date of the continuously deposited sample will be younger. So, if our age is 2490 years BP (on the lower line), the time the deposition started is given by the horizontal projection of the 2490 year point on the lower line to the upper line for an estimated, approximate age of painting of ~5000 years BP. That latter age estimation based on *uniform* oxalate deposition over time will be discussed later in the next section.

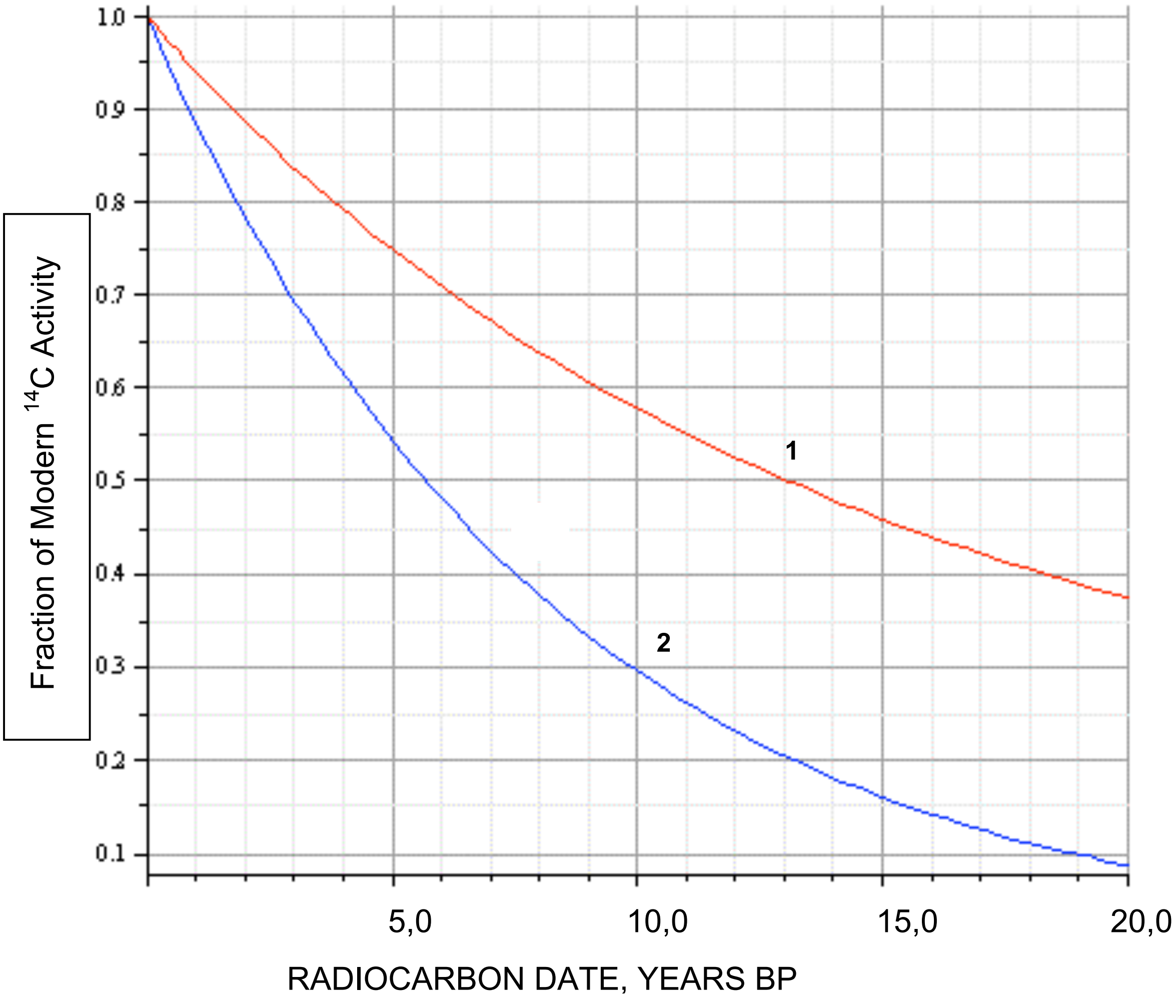

Fig. 2. Calculation of the "age" of the carving by using two assumptions: **1.** oxalate deposited uniformly over time; **2.** oxalate deposited originally in a short time span.

Method 4 – radiocarbon dates of the ocher-pigmented pictograph covered by the calcite layer and other nearby ocher-pigmented paintings: Niéde Guidon also sent us a sample she collected of the red painted image that had been covered by the calcite layer for us to date directly (the left anthropomorphic motif in Fig. 1). Starting in 1990, we developed a plasma-chemical technique that we used to date rock paintings, even those that contained inorganic pigments, i.e. in this case iron ocher (iron oxide, hematite). That technique, developed in our laboratory at Texas A&M University, has been reviewed several times in the past, most recently by (Rowe 2009). We have demonstrated reasonably firmly that the technique works well. See Figs. 3 and 5 in the Rowe (2009) review for graphs that compare our ages with (1) previously dated samples using the standard radiocarbon dating technique and radiocarbon standard samples and (2) with age ranges from archaeological inferences. Agreement is good, but for item (2) which tests the pictograph dates, the archaeologically inferred age ranges are not accurate enough to provide a *stringent* test. We dated the rock painting sample of the anthropomorph sent to us by Dr. Guidon and obtained a radiocarbon age of 3730 ± 90 years BP. That result agrees reasonably well with the uniform deposition rate model of the oxalate date (see section Method 3 above) of 5000 years BP. Of course, one would not expect absolute compliance with a uniform deposition rate of oxalate over millenia. We expect that many climatic factors would vary the oxalate formation rate. The general consistency of those two dates, however, argues for the validity of the 3730 ± 90 years BP date for the red pictograph. Neither are in any way consistent with the Watanabe *et al.* age of >35,000 years. Methods 3 and 4 are not completely independent. Both rely on radiocarbon analysis for the dates. However, the material dated and the pretreatments are completely different for the two.

In addition to the two more or less direct and mutually consistent dates discussed above from our laboratory, we were permitted to collect samples of other nearby paintings with inorganic pigments, both from within the Toca do Serrote da Bastiana shelter and from other shelters nearby. Those ocher-pigmented paintings gave the following ages: 2280 ± 110 years BP at Toca do Serrote da Bastiana; 2700 ± 110 years BP at Toca do Sitio do Maio; and 3570 ± 50 years BP at Toca do Extrema (Rowe & Steelman 2003). Thus all the pictograph ages we determined on the red-pigmented paintings are consistent with the age of the calcite covered pictograph being <3820 years BP.

Method 5 – radiocarbon dates of nearby charcoal pigmented paintings: In addition to the dates produced above, we also collected samples of *charcoal* paintings from within Toca do Serrote da Bastiana and from other nearby shelters to radiocarbon date. The charcoal pictograph dates we obtained were: 1230 ± 50 years BP at Toca da Extrema; 1880 ± 60, 2970 ± 300 and 3320 ± 50 years BP at Toca do Serrote da Bastiana; 2120 ± 110 years BP at Pedra Furada (Rowe & Steelman 2003). Once again all our charcoal pigment dates are consistent with ages of <3820 years BP.

The ten radiocarbon dates from Toca do Serrote da Bastiana, Toca do Extrema, Pedra Furada, and Toca do Sitio do Meio rock painting sites were all less than 3820 years BP. These dates are from three different sub-techniques: radiocarbon dating of calcium oxalate; radiocarbon dating of paintings with inorganic red ocher pigments; and radiocarbon dating of charcoal paintings. These cannot truly be considered to be totally independent techniques, even though the samples are treated completely differently in the three categories. Thus there is considerable evidence that the ages of the rock paintings we have examined are all <3820 years BP. Without the EPR and TL dates on the calcite layer of Watanabe *et al*. discussed above, there is little doubt that these results would be accepted. So for the third time in this paper I say, alas, life is not so simple.

Are EPR and TL the best techniques for dating calcite?

White (2007:143) wrote concerning ESR dating:

> *"An alternative dating technique [alternative to the well established U/Th dating] that also makes use of the uranium incorporated in speleothems* [calcite layers] *…* [is] *electron spin resonance (ESR) spectroscopy (also known as electron paramagnetic resonance (EPR) spectroscopy).* […] *Comparisons between ESR dates and U/Th dates are sparse but agreement between the methods has not been particularly good (Hercman and Lauritzen 1996). No systematic evaluation of thermoluminescence dating seems to have been applied to speleothems [calcite]."*

And another wrote concerning ESR dating:

> *"In principle, in the more favorable cases, and assuming some simplifying hypotheses, the age of a speleothem could be derived from the total radiation dose cumulated by the sample and the annual dose rate to which it was exposed. Unfortunately, not all the samples are suited for ESR dating: indeed, the presence of cationic impurities such as Mn^{2+}, Fe^{2+}, or Fe^{3+}, humic acids (organic matter), can mask the signal of interest, or interfere with it. Moreover, the radiation centers must be stable on geologic time, i.e., to have a very large lifetime, to make dating possible. Many other artifacts, such as, e.g., surface defects induced by the grinding of the sample can also preclude a correct dating. Only a few percents of the samples tested are in fact suitable for dating. This makes the technique often disappointing for the experimentalists. One of the main challenges of the technique is the correct identification of the radiation-induced centers and their great variety related to the nature and the variable concentration of the impurities present in the crystal lattice of the sample. ESR dating can be tricky and must be applied dating a calcite layer."* (http://www.answers.com/topic/speleothem)

I have obviously and perhaps less than objectively (?), argued that our techniques are correct. But some of the same objections that have been raised for the ESR dating might be said about our technique as well. However, we have, in addition to the arguments presented above for the Toca do Serrote da Bastiana and nearby rock art, we have applied all the usual methods for verifying our plasma-chemical techniques. We have dated possibly the only prehistoric rock art with known age: Naj Tunich (Armitage *et al*. 2001). We radiocarbon dated oxalate from a calcite layer with the result of 2490 ± 90 years BP which compared to a result from another laboratory of 2500 ± 1000 years old using U/Th dating. An e-mail from Ewan Lawson (1998), said, "Recent blanks from the TAMU *[Texas A&M University]* laboratory run at the Australian Nuclear Science and Technology Organisation (ANSTO) produced results that introduced "a negligible amount of modern carbon…" compared to "our graphitisation process [that] introduces about 0.0009 mg modern carbon.", *confirming that our radio carbon-free background was low. We have consistently run radiocarbon standards to confirm that we obtain the correct dates (see e.g., Rowe 2009). Further evidence confirming the validity of our technique comes from the consistent dates on several materials from an infant mummy burial package (Steelman* et al*. 2004). Finally, we have shown that our results generally agree with dates expected via archaeological inference (see e.g., Rowe 2009). From these various checks and balances, we are confident that our techniques are verified.*

How can this large discrepancy be resolved?
Uranium/Thorium dating: independent technique for dating calcite

So, in my opinion, the situation cannot be resolved by additional dates from either of the two laboratories using the same techniques used before. As Guidon and Arnaud (1991) wrote in a much broader context:

> *"In the endless debate one might reflect that everything seems to have been said already. The situation does not change: each time there is a discovery, unfailingly the debate takes up again with the same arguments. This results in dogmatic positions and a climate of ideological fervor."*

That probably describes the present situation with regard to the date of the Toca do Serrote da Bastiana pictograph age. Though more than one sub-technique was used by both laboratories, neither laboratory was able to use totally independent methods within their laboratories. An independent technique, preferably from a third laboratory is necessary to resolve the issue -- assuming the new results agreed with either the University of São Paulo University or the Texas A&M University results. We eagerly await such determinations. The age of the painting in Toca do Serrote da Bastiana that was covered by the dated calcite layer is far too important to leave unresolved.

Fortunately, there are other, independent techniques available for dating the calcite layer. Probably the best method for dating calcite overall, and certainly as in this case for an independent method of comparison, is almost unquestionably that of uranium-thorium dating. It is a well accepted technique. White (2007:143) also wrote concerning U/Th and ^{14}C dating:

> *"Such methods as U/Th dating and ^{14}C dating are well established. U/Th dating has been widely used for dating speleothems in caves for over 60 years. It is a method whose assumptions are completely different from those of TL, EPR and the radiocarbon dating of the calcium oxalate contained within the calcite layer."*

That makes it an ideal technique to use for testing the results of the two laboratories discussed here. It is hoped that Dr. Guidon will try to get a U/Th dating laboratory into this controversy. A third independent date is essential to resolve the current discrepancy.

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BIBLIOGRAPHY

ADAVASIO J. & PAGE J. 2002. — *The First Americans: In Pursuit of Archaeology's Greatest Mystery*. New York, NY: Random House.

ARMITAGE R.A., BRADY J.E., COBB A., SOUTHON J.R, ROWE M.W. 2001. — Mass Spectrometric Radiocarbon Dates from Three Rock Paintings of Known Age. *American Antiquity,* 66, p. 471-480.

BORRERO L.A. 1995. — Human and natural agency: some comments on Pedra Furada (Brazil). *Antiquity,* 69, p. 620-603.

COLLINS M.B., HESTER T.R., OLMSTEAD D., HEADRICK P.J. 1991. — Engraved cobbles from early archaeological contexts in central Texas. *Current Research in the Pleistocene,* 8, p. 13-15.

DENNELL R.W. & HURCOMBE L.M. 1995. — Comment on Pedra Furada. *Antiquity,* 69, p. 604-605.

DILLEHAY T. 2000. — The *Settlement of the Americas: A New Prehistory*. New York, NY: Basic Books.

FEYNMANN R. 1999. — *The Pleasure of Finding Things Out*: *The best short works of Richard P. Feynman*. Cambridge: Perseus Books.

GOEBEL T., WATERS M.R., O'ROURKE D.H. 2008. — The Late Pleistocene dispersal of modern humans in the Americas. *Science,* 319, p. 1497-1502.

GUIDON N. & ARNUAD G.1991. — The chronology of the New World: two faces of one reality. *World Archaeology,* 23, p. 167-178.

GUIDON N. & DELIBRIAS G. 1986. — Carbon-14 dates point to man in the Americas 32,000 years ago. *Nature,* 321, p. 769-771.

HASSIBA R.G., CIESLINSKI B., CHANCE B., AL-MAIMI F.A., PILANT M., ROWE M.W.2011. — How Old Are the Qatari Jabal Jassasiyah Petroglyphs? *Qatar Museum of Antiquities Publication*, in press.

HESTER T., COLLINS M.B., HEADRICK P.J. 1992 . — Paleo-Indian engraved stones from the Gault site. *La Tierra*, 19, p. 3-5.

METZLER D. 2009. — First Peoples in a New World: Colonizing Ice Age America. Berkeley: University of Calfornia Press.

METZLER D., ADAVASIO J.M., DILLEHAY T.D. 1994. — On a Pleistocene human occupation in Pedra Furada. Brazil. *Antiquity,* 68, p. 695-714.

OPPENHEIMER J.R. 1951. — Encouragement of science. *Bulletin of the Atomic Scientist,* VII (1), p. 6-8.

PARENTI F., FONTUGUE M., GUERIN C. 1996. — Pedra Furada in Brazil and its 'presumed' evidence: Limitations and potential of the available data. *Antiquity,* 70, p. 416–421.

PESSIS A.-M. & GUIDON N. 2009. — Dating rock art paintings in Serra da Capivara National Park. *Adoranten*, I, p. 49-59.

ROWE M.W. 2007. — Reflections on the dating of rock art. *In:* REDDY P.C. (ed.), *Exploring the Mind of Ancient Man*, p. 218-231. New Delhi: Research India Press.

ROWE M.W. 2009. — Radiocarbon dating of ancient rock paintings. *Analytical Chemistry,* 81, p. 1728-1735.

ROWE M.W. & STEELMAN K.L. 2003. — Comment on "Some evidence of a date of first humans to arrive in Brazil". *Journal of Archaeological Science,* 30, p. 1349-1351.

RUIZ J.F., MAS M., HERNANZ A., ROWE M.W., STEELMAN K.L., GARVIRA J.M. 2009. — First radiocarbon dating of oxalate crusts over Spanish prehistoric Rock Art. *International Newsletter of Rock Art [INORA],* 46, 1-5.

RUIZ LÓPEZ J.F., ROWE M.W., HERNANZ GISMERO A., GAVIRA VALLEJO J.M., VIÑAS VALLVERDÚ R., RUBIO I MORA A. 2009. — Cronología del arte rupestre postpaleolítico y datación absoluta de pátinas de oxalato cálcico. Primeras experiencias en Castilla – La Mancha (2004-2007). *In:* LÓPEZ MIRA J.A., MARTÍNEZ VALLE R., MATAMOROS de VILLA C. (coord.), *El Arte Rupestre del Arco Mediterráneo de la Península Ibérica*, *10 años en la lista del Patrimonio Mundial de la UNESCO*, Actas IV Congreso (Valencia, 3, 4 y 5 de diciembre de 2008), p. 280-294. Valencia: Generalitat Valenciana.

RUSS J., PALMA R.L., LOYD D.H., BOUTTON T.W., MCCOY M.A. 1996. — Origin of the whewellite-rich crust in the Lower Pecos region of southwest Texas and its significance to paleoclimate reconstructions. *Quaternary Research,* 46, p. 27-36.

RUSS J., KALUARCHI W.D., DRUMMOND L., EDWARDS H.M.G. 1999. — The nature of a whewellite-rich rock crust associated with pictographs in southwestern Texas. *Studies in Conservation,* 44, p. 91-103.

RUSS J., LOYD D.H., BOUTTON T.W. 2000. — A paleoclimate reconstruction for southwestern Texas using oxalate residue from lichen as a paleoclimate proxy. *Quaternary International,* 67, p. 29-36.

SANTOS G.M., BIRD M.I., PARENTI F., FIFIELD L.K., GUIDON N., HAUSLADEN P.A. 2003. — A revised chronology of the lowest occupation layer of Pedra Furada rock shelter, Piaui, Brazil: the Pleistocene peopling of the Americas. *Quaternary Science Reviews,* 22, p. 2303-2310.

STEELMAN K.L., RICKMAN R., ROWE M.W., BOUTTON T.W., RUSS J., GUIDON N. 2002. — Accelerator mass spectrometry radiocarbon ages of an oxalate accretion and rock paintings at Toca do Serrote da Bastiana, Brazil. *In:* JAKES K.A. (ed.), *Archaeological Chemistry: Materials, Methods, and Meanings,* p. 22-35. Washington, DC: American Chemical Society. (ACS Symposium Series; 831).

STEELMAN K.L., ROWE M.W., TURPIN S.A., GUILDERSON T., NIGHTENGALE L. 2004. — Non-destructive radiocarbon dating: naturally mummified infant burial bundle from SW Texas. *American Antiquity,* 69, p. 741-750.

THOMAS M., GILBERT P., JENKINS D.L., GOTHERSTROM A., NAVERAN N., SANCHEZ J.J., HOFREITER M., THOMSEN P.F., BINLADEN J., HIGHAM T.F.G., YOHE II R.M., PARR R., SCOTT CUMMINGS L., WILLERSLEV E. 2008. — DNA from pre-Clovis human coprolites in Oregon, North America. *Science,* 320, p. 786-790.

WATANABE S., AYTA W.E.F., HAMAGUCHI H., GUIDON N., LA SALVIA E.S., MARANCA S., BAFFA FILHO O. 2003. — Some evidence of a date of first humans to arrive in Brazil. *Journal of Archaeological Research,* 30, p. 351-354.

WATCHMAN.A. 1993. — Evidence of a 25,000-year-old pictograph in northern Australia. *Geoarchaeology,* 8, p. 465-473.

WATCHMAN.A. & CAMPBELL J. 1996. — Microstratigraphic analysis of laminated oxalate crust in northern Australia. *In:* 2nd *International Symposium on the Oxalate Films in Conservation of Works of Art, Milan, Italy*, p. 409-422.

WATERS M.R. & STAFFORD T.W. 2007. — Redefining the age of Clovis: Implications for the peopling of the Americas. *Science,* 315, p. 1122-1126.

WHITE W.B. 2007. — Paleoclimate records from speleothems in limestone caves. *In:* SASSOWSKY I.D. & MYLROIE J. (eds.), *Studies of Cave Sediments: Physical and Chemical Records of Paleoclimate*, p. 135-175. Dordrecht, The Netherlands: Springer.

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