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Contents

Cover image: *Digital recreation of what the Point Puer Boys' Prison may have looked like in 1845, when the population of the prison peaked at approximately 800 juvenile inmates (created by John Stephenson, May 2013; see pages 89-94)*

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DigIt

Editorial

Dig It is a community product. The total number of people involved in writing, editing, formatting, reviewing, layouting and printing this issue were 39 from 24 different institutions – and that does not even include the greater number of people who provide helpful comments and ideas along the way, or write and talk to us to let us know they appreciate our work – all of which are very important things to keep us going. Special thanks goes out to ArchSoc, who are always there in the background offering practical help at the most critical times.

Compared to the 2014-1 issue, this second issue of 2014 has a more local touch, but still includes reports about archaeological work being done in places as far away as Thailand, Italy, the UK, and South America. We are proud to have encouraged a number of undergraduate and Masters students to publish their thoughts and research. We want to particularly develop this part of the journal by encouraging fresh new authors to share their ideas. One step towards this goal was a book review Master Class, held in November together with Dr Alice Gorman, book review editor of *Australian Archaeology*, that encouraged 16 students to write reviews for *AA* and *Dig It* – two of which readers can find in this issue.

And since *Dig It* is a community product many editors and review panel members will stay on in 2015 when Jordan Ralph will take over editor-in-chief with new ideas and enthusiasm. During the last weeks, we have been preparing ideas for making *Dig It* even more successful in the future. The 2014 *Dig It* team would like to thank ArchSoc for giving us the opportunity to be part of a rewarding and creative experience. I personally would like to thank all authors, editors, and reviewers for the hard work and dedication that is needed to create one of only three peer-reviewed archaeology student journals in the world: *Dig It*!

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ArchSoc members during Total Station and GPS workshops (photographs by Dianne Riley, 2014)

President's Address

The second half of 2014 was a busy one for the Flinders Archaeological Society. During this period not only did the Society support University events such as O'week in late July and the Open Day in early August, it undertook a new direction. Under the guidance of a new look Executive Committee, ArchSoc organised a series of workshops in order to allow members the opportunity to further develop their professional skills. Participants came together in a relaxed atmosphere and in total three workshops have been held since July; two Total Station workshops (August and September), and a GPS workshop (October). Thanks is especially given to the two professionals, Rob Koch and Jordan Ralph, who gave their time pro bono to ArchSoc, and who also committed to undertaking further workshops in 2015. ArchSoc continued to support the Flinders University Department of Archaeology's Thursday Seminars in 2014 and looks forward to continuing to do so in 2015. In November, ArchSoc also supported the Book Review Master Class with Dr. Alice Gorman.

In October, ArchSoc was asked to take part in the Highercombe Museum Vintage Fair. This was a direct result of the involvement of ArchSoc members in the public archaeology event carried out during *About Time: South Australia's History Festival* in May. As a result of its connection with Highercombe, ArchSoc went on to present a brief overview of the value of potential relationships with branches of the National Trust, at the State Conference of the National Trust of South Australia on 19th November. This presentation was undertaken with a view to setting up future opportunities of field work and research for ArchSoc members.

Overall, however, membership was down for 2014 and this is something that needs to be addressed in 2015. Membership fees will, however, remain at $15, with no concessions, for the coming year. The ArchSoc 5-year-plan (a product of the Forum held in November) is exciting and offers future committees the benefit of an in-place strategy for the future direction of ArchSoc.

In review, 2014 has been an innovative and productive year. To ensure that the vision for the future direction of ArchSoc materialises, continued energy and commitment from all ArchSoc members will be needed in 2015.

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Dianne Riley, Adeena Fowke and Aletta Fowke at the ArchSoc stall, Flinders University O'week (photograph by Susan Arthure, July 2014)

Neutron Activation Analysis (NAA):

What is it and how is it useful for archaeological investigation?

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Abstract

Neutron activation analysis (NAA) is a powerful quantitative analytical technique with applications in a range of fields including archaeology. Due to its outstanding sensitivity, accuracy, precision, and versatility the technique is a suitable method for analysing many different types of archaeological material. Archaeologists have utilised neutron activation analysis for the purpose of characterising archaeological materials such as ceramics, lithics and glass with the goal of determining their provenance. This paper provides a brief introduction to the technique and its history in archaeological investigation and provides examples of how NAA has been used for addressing archaeological questions.

Introduction

Archaeological chemistry is an interdisciplinary field of archaeological research in which techniques and approaches from the chemical, biological, physical, geological, and statistical sciences are employed to extract information from the material record. Archaeological chemistry is also called 'archaeometry' which was coined by Christopher Hawkes in the 1950s to describe the increased emphasis on dating, quantification, and physic-chemical analysis of archaeological material (Pollard et al. 2007:9). The application of chemical analytical methods to archaeological materials in support of provenance research has grown rapidly over the past few decades (Glascock and Neff 2003:1516). Provenance research involves the use of compositional profiles of artefacts and source materials to trace individual artefacts from their find spot to their place of origin (Glascock and Neff 2003:1516; Wilson and Pollard 2001:507). The information gathered is used to investigate archaeological questions including identification of prehistoric production areas, the identification of trade and exchange routes of raw materials and artefacts as well as the mobility patterns of prehistoric peoples (Glascock and Neff 2003:1516). Although a number of techniques have been employed to characterise archaeological materials, the analytical method with one of the longest and most successful histories of application for provenance research has been neutron activation analysis (NAA) (Glascock and Neff 2003:1516).

A history of neutron activation analysis

As early as the 1840s and 1850s, pioneering work by European chemists led to the scientific acceptance that some chemical properties of an archaeological artefact could be considered characteristic of the raw material source of that object – the 'chemical fingerprint' was born (Pollard and Heron 1996; Whitbread 2001; Wilson and Pollard 2001:507).

From the 1960s onwards, a 'golden age' of archaeological chemistry was established. This period saw an increasing number of archaeological artefacts being subjected to chemical provenancing; these included ceramics, non-ferrous metals, lithics, glasses and faience, and a selection of organic raw materials including amber and jet (Wilson and Pollard 2001:507). In order to accommodate the need to analyse large numbers of samples, and a large number of characteristics on each sample, focus shifted during the 1970s to statistical manipulation of multivariate data (Baxter 2008; Wilson and Pollard 2001). Mathematical treatment of data sets rapidly became an integral feature of provenance work and systematic methodologies were advocated (Wilson and Pollard 2001:507). The mathematical treatment of the data is explored in more detail later in this paper. By the 1990s NAA was regarded as the technique of choice for provenance research (Glascock and Neff 2003). Now NAA is most frequently used in collaboration with mineral approaches since mineral and elemental approaches each provide unique but primarily complementary results (see Alden et al. 2006; Bertolino and Fabra 2003; Bishop and Blackman 2002; Bray et al. 2005; D'Altroy and Bishop 1990; Falabella et al. 2013; Glascock and Neff 2003; Sziágyi et al. 2012).

Neutron activation analysis

Neutron activation analysis is a sensitive technique useful for qualitative and quantitative multi-element analysis of major, minor and trace elements present in many sample matrices (Glascock and Neff 2003:1516). This technique has been applied to the study of archaeological material since the 1960s. Since the mid-1970s it has been the preferred analytical technique for archaeologists in addressing questions relating to the procurement and use of raw materials and the trade or exchange of finished goods (Bishop and Blackman 2002).

In general, the analytical technique is based on the interaction of neutrons with the nucleus of atoms to produce radioactive isotopes, the quantity of which can be used to determine the elemental concentration of the sample (see Alden et al. 2006:577; Bishop and Blackman 2002:603; Glascock and Neff 2003:1516). When neutrons interact with the nuclei of atoms, radioactive isotopes may be formed through neutron capture (see figure 1), the type of interaction depends upon the energy of the neutron (see Alden et al. 2006:577; Bishop and Blackman 2002:603; Glascock and Neff 2003:1516). The newly formed isotope release energy through several means, including the emission of electromagnetic energy in the form of gamma-rays (see Alden et al. 2006:577; Bishop and Blackman 2002:603; Glascock and Neff 2003:1516). Gamma-ray energies are characteristic of the radioactive nucleus undergoing decay. There are two methods to quantify the gamma-ray counts through 1) the use of standards of certified NIST (National Institute of Standards and Technology)

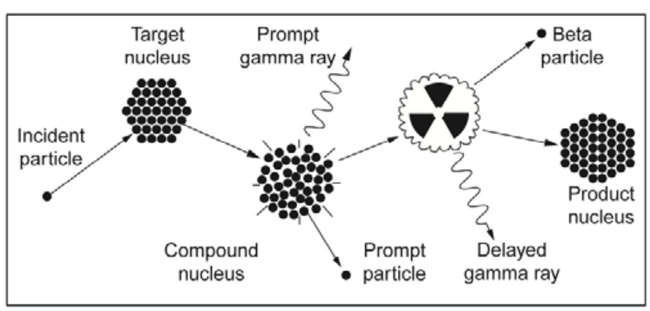

Figure 1: Demonstrating neutron capture (Glascock and Neff 2003:1518)

reference materials or 2) the k_0 method. Both methods result in the compositional certification of the material being analysed (see Bennett et al. 2012; Bishop and Blackman 2002; Popelka-Filcoff et al. 2012 for more detail about these methods).

Essentially the process results in the chemical composition of a sample being identified, which can either be clustered together to understand which samples were made locally and which were traded in or it can be compared to samples of known sources and possibly traced back to the original source location (see Figure 2 for the two possible approaches of source determination).

Statistical analysis

Once the elemental composition has been collected the next step in any compositional analysis is to determine if there are any distinct groups present in the data set that support a meaningful archaeological interpretation (Glascock et al. 2004). The amount of data that is generated in NAA research is often substantial, consisting of up to 75-92 elements measured depending on the sample (see Rice 2005:397; Bishop et al. 1982:292). Due to the large quantity of data, multivariate statistical analysis is often required to identify and quantify the similarities and differences between specimens and groups of specimens (Glascock et al. 2004). Groups defined by compositional data can be viewed as "centers of mass" in the compositional hyperspace described by the measured element concentrations. An individual group is characterised by the location of its centroid and the unique correlations of element concentrations to one another (Glascock et al. 2004; Popelka-Filcoff 2006). Pattern recognition methods such as cluster analysis, plots of the original data in two and/or three dimensions, and principle components analysis (PCA) are customary approaches to data handling (Glascock and Neff 2003; Popelka-Filcoff et al. 2007). These methods have been described extensively elsewhere (see Baxter 2008) and will only be described briefly here.

Cluster analysis

Cluster analysis is a general term that applies to a variety of specific techniques but the essential components are a measure of the similarity-dissimilarity between specimens (i.e. distance) and an algorithm that groups specimens on the basis of the defined measure (Baxter 2001:688; Glascock and Neff 2003:1522). The results of cluster analysis are generally presented in the form of dendrograms that show the order and level of specimen clustering. Because interpretation of dendrograms is highly subjective, it is normally only used to identify possible groups after which other techniques are employed for group refinement and classification (Glascock and Neff 2003:1522).

Bivariate and trivariate plots

Bivariate and trivariate plots are used to examine the correlations between variables, identify obvious groups and detect outlier specimens. Confidence ellipses (e.g. probability intervals) are usually drawn around groups to emphasize the differences between groups or to show the associations between individual specimens and known groups (Glascock and Neff 2003:1522).

Principle component analysis

Principle component analysis (PCA) involves a transformation of the dataset on the basis of eigenvector methods to determine the magnitude and direction of maximum variance in the dataset distribution in hyperspace (Baxter 2001:688; Glascock and Neff 2003:1522). The PCA transformation provides a new basis for viewing the entire data distribution to reveal structure not readily observed when plotting the original variables (see Baxter 2001:688; Glascock and Neff 2003:1522 for more information).

Provenance postulate

The basic proposition underlying chemistry-based provenance determination was understood by the early 1970s (see Glascock and Neff 2003:1521; Harbottle 1976). But it was Weigand et al. (1977) who first stated plainly that the effort to link artefacts to sources through compositional analysis depends on the postulate 'that there exists a difference in chemical composition between different natural sources that exceed, in some recognizable way, the differences observed within a given source' (also see Glascock and Neff 2003:1521; Harbottle 1976; Neff 2000; Wilson and Pollard 2001:507-508). This statement is known as the 'provenance postulate' and the major assumptions underlying every provenance study can be summarised as followed (adapted from Wilson and Pollard 2001:507-508):

1. The prime requirement is that some chemical characteristic of the geological raw material(s) is carried through (unchanged, or predictably relatable) into the finished object.
2. That this 'fingerprint' varies between potential geological sources available in the past, and that this variation can be related to the geographical (as opposed to perhaps a broad depositional environment) occurrence of the raw material. Inter-source variation must be greater than intra-source variation for successful source discrimination.
3. That such characteristic 'fingerprints' can be measured with sufficient precision in the finished artefact to enable discrimination between competing potential sources.
4. That no 'mixing' of raw materials occurs (either before or during processing, or as a result of recycling of material), or that any such mixing can be adequately accounted for.
5. That post-depositional processes either have negligible effect on the characteristic fingerprint, or that such alteration can either be detected (and the altered elements or sample be discounted), or that some satisfactory allowance can be made.
6. That any observed patterns of trade or exchange of finished materials are interpretable in terms of human behaviour. This pre-supposes that the outcome of a scientific provenance study can be interfaced with an existing appropriate socio-economic model, so that such results do not exist in vacuo.

These major assumptions underlie all provenance studies. While some of them appear to be commonsense these assumptions must always be acknowledged when undertaking provenance-based research. These assumptions are particularly important when using techniques such as NAA as any modification to the studied material before it was deposited in the archaeological record can alter its elemental composition. This issue of chemical composition alteration is discussed in more detail later in this paper.

Provenance Determination

Source determination efforts based on the provenance postulate can follow one of two separate paths (see figure 2) as explained by Glascock and Neff (2003:1521):

If the sources are localized and relatively easy to identify, as in the case of volcanic obsidian flows, raw materials from the known sources are usually characterized and then artefacts of unknown provenance can be compared to the range of variation of the known source groups. On the other hand, if sources are widespread, as is especially true in the case of ceramic raw materials, the prospect of sampling and characterizing most or all of the possible sources are impractical. As a result, ceramic provenance research generally involves an alternative approach by which reference groups are created from the unknown ceramic samples. In this more common approach to ceramic sourcing, individual raw material samples are compared to the range of variation between ceramic reference groups.

Using NAA on different archaeological material

The application of NAA on archaeological material is well established in the literature. Some materials such as obsidian, ochre, ceramic and clay have been studied more exhaustively than others. Other materials such as steatite, pipestone, turquoise, limestone, marble, basalt, ancient glass, native copper, coins and other archaeological material have been analysed by NAA with various degrees of success for archaeological interpretation (see Harbottle 1976; Glascock and Neff 2003:1522; Truncer et al. 1998; Wilson and Pollard 2001:512-514). Below is a summary of some of the issues and concerns associated with the three main materials followed by examples that illustrate the potential of these analyses in addressing archaeological questions.

Ceramics and clays

Ceramics and clays constitute the vast majority of provenance studies undertaken (see Neff 1992 for a review). Ceramics provide a challenge as there is a great degree of anthropogenic manipulation of the raw material in processing the clay into ceramics (see Rice 2005:113-166 for a full discussion). Clays are very ubiquitous and their geological histories are so varied that the reliability of distinguishing between natural sources varies widely (Glascock and Neff 2003:1522). Unfortunately, geological processes of clay formation often do not create discrete, chemically homogenous sources but instead produce extensive deposits that vary in composition (Glascock and Neff 2003:1522). The chemical composition of clay deposits is a complex product of the mineralogy of the rocks from which the clay is derived, the weathering and transport processes responsible for producing the clay deposit and the chemical environment in which the clay is deposited and matured (Wilson and Pollard 2001:511). Clays are processed, e.g., washing, weathering, levigating, mixing clays from more than one deposit and adding temper before the final vessel is made (Wilson and Pollard 2001:511). Ceramics are then fired at temperatures possibly between 700 °C and 800 °C in a simple bonfire. Finally, post-depositional geochemical and mineralogical alteration can also affect the chemical composition of a ceramic sherd and vessel (Wilson and Pollard 2001:511). All of these factors need to be considered when undertaking NAA on ceramic and clay samples. Below are two examples of how researchers have used NAA to analyse the composition of ceramic and clay samples in order to address archaeological questions.

NAA research can provide new insights into traditional archaeological approaches to ceramic analyses as a study conducted by Bray et al. in 2005 demonstrates. Bray et al. (2005) illustrates the potential issues with the use of traditional classification schemes of Inka ceramics (e.g., provincial, imperial and local), which are prevalent in the literature, as they are based on simple, visual and subjective observations based on style (Bray et al. 2005:98). Bray et al. (2005) analysed ceramics from sites in southern Peru and northwest Argentina which were associated with an Inkan ceremony known as *capacocha*. This ceremony, which served to link the capital Cusco to its peripheries, included the sacrifice of precious objects (e.g., imperial ceramics) as well as human sacrifices (Bray et al. 2005). Traditionally it was assumed that the ceramics were traded in from the capital Cuzco to all areas of the empire for these ceremonies; however, after elemental analysis was conducted it was clear that the imperial ceramics were made using local clay and that local potters had adopted the stylistic appearance of imperial Inka ceramics (Bray et al. 2005). While this study was small (29 samples), it illustrates the issues associated with an over-reliance on stylistic analysis and the potential for analytical techniques to provide new independent information.

NAA can be used to investigate long distance trade routes and interregional interaction. However it can also be used to investigate localised trade and interactions. Alden et al. (2006) conducted NAA on 157 ceramic and clay samples from two sites in northern Chile during the Inka period. This investigation revealed two

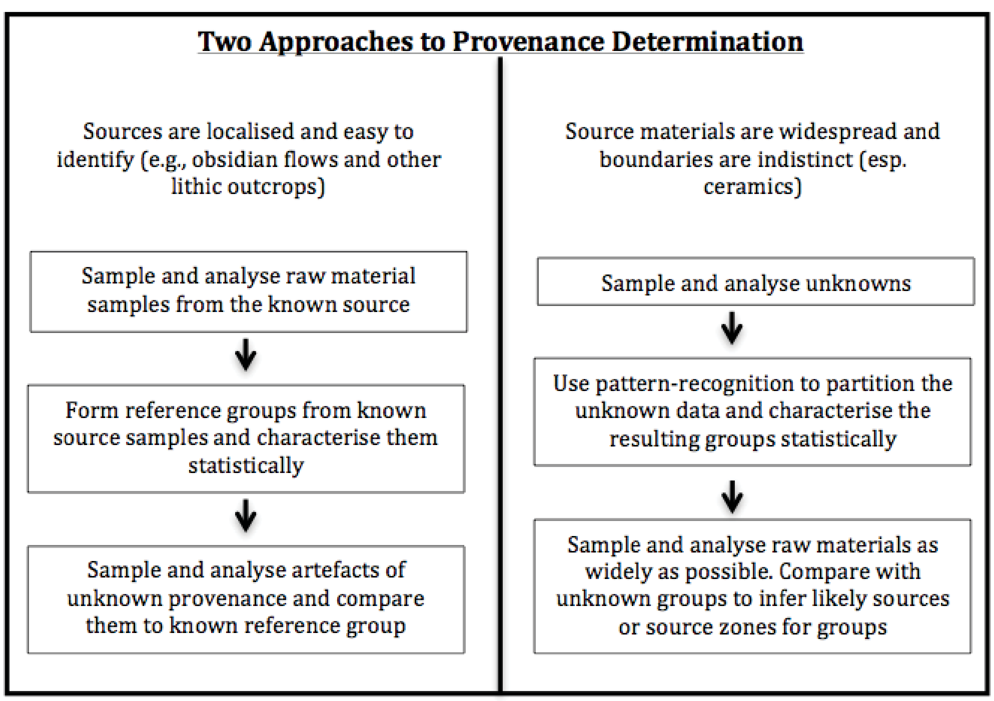

Figure 2: Two approaches to provenance determination (from Glascock and Neff 2003:1521)

major and three minor compositional groups of ceramics. The major groups are linked to local clay sources found in northern Chile while one of the minor groups is made up of ceramics imported from northwestern Argentina. The distribution of the compositional groups indicates that, in this region, patterns of ceramic production differed for different vessel types: jars were made from clay and temper acquired near the sites where jars were used, while bowls were made of material coming from more distant sources. Additionally, the study also demonstrated that Inka-style ceramics were being locally produced at sites in the region during the Inka period, which also draws on the conclusions of the previous example about the issues of using stylistic features to identify interregional interactions.

Ochre

Ochre is a significant material in Aboriginal Australian cultural expression from ceremonial uses to its application on many types of artefacts. Across the Australian continent, ochre with associated cultural meaning and particular physical qualities was used and traded between cultural groups (Popelka-Filcoff et al. 2011). Ochre is not only important in Aboriginal Australian culture but also for cultures all around the world (Popelka-Filcoff et al. 2011).

NAA on ochre (iron oxide pigment) has been done on archaeological artefacts in South America and is now being conducted in Australia (Popelka-Filcoff 2006; Popelka-Filcoff et al. 2007; Popelka-Filcoff et al. 2011; Popelka-Filcoff et al. 2012). NAA is sensitive enough to determine compositional difference between major sources of ochre. A paper by Popelka-Filcoff et al. 2012 illustrates the potential of NAA research on Australian ochre quarries as a tool to determine provenance. This study considered 128 ochre samples from 13 South Australian ochre quarry sites. The results show that distinct compositional groups can be identified. This research has demonstrated not only that NAA is a sufficiently sensitive technique to differentiate between ochre quarries but also has illustrated the archaeological potential for NAA research on ochre as a way to aid in our understanding of trade routes in the past (Popelka-Filcoff et al. 2012). As this study included ochre quarries it can act as a database where ochre on artefacts or ochre found in excavations can be compared to and an understanding of where that ochre may have originated can potentially be inferred. The application of NAA to Australian ochre is only beginning and the possibilities for addressing archaeological questions about trade and exchange are great.

Lithics

Chert and flint are sedimentary rocks high in quartz that were commonly used in tool making and for which source determination by chemical characterisation is often challenging. There have been some studies that report success in differentiating source locations for chert (see Hoard et al. 1992, 1993 and Selivanova et al. 1998). However other studies that have tried to distinguish chert outcrops have failed (see Cackler et al. 1999) to produce reliable source distinctions. Clearly the geographical extent and geological context of chert sources are crucial to determining whether chert provenance analysis will yield answers to archaeological questions (Glascock and Neff 2003:1521).

Obsidian artefacts are comparatively easy to source by chemical analysis. Most obsidian sources are extremely homogenous and the volcanic sources are geographically limited to certain regions (Glascock and Neff 2003:1521). Obsidian is high in silica, but the trace and minor element ingredients sometimes differ between sources (Glascock and Neff 2003:1521). If all possible sources have been sufficiently characterised, the reliability of matching an obsidian artefact to its proper source is excellent and the number of elements required to identify the source may in fact be very small (Glascock and Neff 2003:1521). However, the reliability of obsidian sourcing is sometimes challenged by weathering sand erosion which may displace obsidian cobbles far from their source.

Finally, a study conducted by Craig et al. 2010 used NAA to determine the elemental composition of obsidian artefacts from Peru. Obsidian artefacts have been identified in archaeological sites along the northern Lake Titicaca Basin. The use of NAA on these artefacts was able to determine distinct chemical grouping (see Craig et al. 2010:573). The research was able to determine that some obsidian artefacts were found more than 120km from the source, and that one-third of the obsidian artefacts found at a site called Macusani were from non-local sources 215km to the southwest. This study illustrates the potential of NAA in identifying long distance trade and exchange. Additionally this study demonstrates the impact that NAA results can have on current understandings and theories related to trade or exchange.

Summary

The potential of NAA as a provenancing tool is already well established in the literature (see Alden et al. 2006; Anderson et al. 2011; Bray et al. 2005; Craig et al. 2010; Glascock et al. 2004; Popelka-Filcoff et al. 2007). This elemental technique has been used on a range of archaeological material to determine the elemental composition and as a result has been used to make interpretations about the past. Archaeological questions that can be addressed with the use of NAA include: identification of prehistoric production areas, the identification of trade and exchange routes of raw materials and artefacts as well as the mobility patterns of prehistoric peoples (Glascock and Neff 2003:1516). It is important that archaeologists are not only aware of these analytical techniques but are able to interpret the data that is produced with a full understanding of both the technique's potential and also its limitations.

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