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Technical considerations and methodology for creating high-resolution, color-corrected, and georectified photomosaics of stratigraphic sections at archaeological sites

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ABSTRACT

Using a conventional, off-the-shelf digital single lens reflex camera and flashes, we were able to create high-resolution panoramas of stratigraphic profiles ranging from a single meter to over 5 m in both height and width at the Middle Stone Age site of PP5-6 at Pinnacle Point, Mossel Bay, South Africa. The final photomosaics are isoluminant, rectilinear, and have a pixel spatial resolution of 1 mm. Furthermore, we systematically color-corrected the raw imagery. This process standardized the colors seen across the photomosaics while also creating reproducible and meaningful colors for relative colorimetric analysis between photomosiacs.

Here, we provide a detailed discussion about the creation and application of our photomosaics. In the first part of the paper, we examine the specific characteristics of modern digital single lens reflex (DSLR) cameras and lenses that were important to us in developing our methodology. We also provide a detailed discussion about how to reproduce the methodology in the field and to post-process the imagery. In the final section of the paper, we give several examples to show how we apply our photomosaics within an empirical 3D GIS database. These examples are provided to show how photographic data can be integrated with other digitally-captured data and used to study the relationships between the stratigraphic features seen in the photomosaics and the 3D distribution of excavated archaeological piece-plots, geochronological samples, and other kinds of geological samples.

1. Introduction

Archaeological fieldwork has made continual progress in its ability to capture information from the past that is archived in sediments. The different fields of archaeology (complex society, classical, Paleolithic, etc.) though are driven by different questions and these differing questions have pushed fieldworkers to strive to capture different types of information. In Paleolithic fieldwork, a fundamental goal has been to increase the resolution of our data capture so as to refine our understanding of a record that in many cases is produced by hunting and gathering peoples whose economy was such that they left behind very light traces of their activities. Add to this the withering forces of taphonomic processes operating over extraordinary timescales and the Paleolithic archaeologist is typically left with a record that appears frustratingly coarse and maddeningly devoid of information.

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A number of techniques have been developed over the years to tease more diverse and detailed types of information from the sedimentological records at Paleolithic sites. Advances in geochronological, geological, and paleoenvironmental sciences in particular have given Paleolithic archaeologists a much fuller picture of the time and processes involved in the formation of sites (for example, Albert and Marean, 2012; Albert and Weiner, 2001; Bernatchez, 2008; Goldberg and Berna, 2010; Henry et al., 2014; Jacobs et al., 2008; Karkanas et al., 2000, 2007; Madella et al., 2002; Schiegl et al., 2004; Wintle and Murray, 2006; Yoshida et al., 2000). Archaeological deposits must be studied within the context of these sedimentological and stratigraphic frames of reference in order to understand how these records were formed and transformed by various diagenetic processes including geogenic, biogenic, and anthropogenic activities. These changes are often revealed through subtle variations in the color and texture of the sediments seen in stratigraphic sections (Karkanas et al., in press).

The inherently destructive nature of archaeological excavation has also driven the concurrent development of new and better ways to document how a site was dug and what was observed during the excavation process. Traditional surveying devices like total stations have dramatically improved the accuracy of excavation measurements at many Paleolithic sites, allowing for the capture of fine details – like stratigraphic layers or artifact lenses – that would have been otherwise missed with relatively imprecise tape measuring (Dibble et al., 2007; Marean et al., 2010; McPherron, 2005; McPherron et al., 2005). Next generation mapping techniques using close-range photogrammetry and terrestrial laser or structured light scanners are also poised to vastly improve field collection methods of site contexts, including complex geometric surfaces like cave walls (Lerma et al., 2014; Remondino, 2011; Rüther et al., 2009), artifact locations (McPherron et al., 2009), artifact analysis (Shott, 2014; Sumner and Riddle, 2008), and depositional events (Sanger, 2015). An added benefit of these methods is that photographs are often taken during the data collection process using conventional, off-the-shelf digital cameras (De Reu et al., 2013). What these images provide is a visual archive of a site to record features like rock art, which are difficult to map (Chandler et al., 2007; Gonzalez-Aguilera et al., 2009; Lerma et al., 2010), but they can also be used to create photorealistic 3D surfaces of the excavations (De Reu et al., 2014).

Recent developments in digital cameras and lenses have also improved the performance and clarity of images taken under low-light conditions, like in the caves and rock shelters that are common to Paleolithic sites. Post-processing techniques are even able to precisely correct geometric effects, image colors, and merge numerous images into seamless, high-resolution photomosaics that provide unprecedented detail for archival or analytical purposes. These improvements and others, like high definition range photography (Wheatley, 2011), though are being squandered by a persistent underutilization of digital photography within the archaeological sciences. Digital cameras – albeit used frequently and for a variety of purposes – seem to be simply taken for granted or assumed to be good enough if the camera has so many "megapixels" or if the image looks decently exposed (but see, Verhoeven, 2008). There has been no critical discussion, for example, about when it is appropriate to use a Digital Single Lens Reflex (DSLR) camera versus "point-and-shoot", tablet, or phone cameras. Similarly, while the color and quality of photographs taken by many 3D scanners may be good enough to texture those models, these devices are still primarily a scanning tool and secondarily a photographic tool. One must remain critical about the quality and characteristics of these images, such as their lighting or oblique projection from a fixed point, for applications beyond model texturing.

Conventional off-the-shelf digital cameras therefore should not be regarded merely as implements that provide pretty pictures rather than tools that can be used to collect valuable scientific data in their own right. Here, we present the results of a photographic study from the site of Pinnacle Point PP5-6, South Africa to create high-resolution photomosaics of complex stratigraphic sections using a conventional, off-the-shelf DSLR camera. Our study was focused on producing the highest image quality and we discuss what characteristics were important to us in developing this quality, choosing our equipment, and implementing our methodology. We also show how we systematically color-corrected our imagery to create reproducible and meaningful colors for relative colorimetric analyses. In the last section of this paper we describe how we use our photomosaics within an empirical 3D GIS database. We do this 1) to show how photographic data can be integrated with other digitally-captured data and 2) to study the relationships between the stratigraphic features seen in the photomosaics and the 3D distribution of excavated archaeological piece-plots, geochronological samples, and other geological samples.

2. Pinnacle point, Site PP5-6

Site PP5-6 is a rock shelter on the south coast of the Western Cape Province of South Africa, near the city of Mossel Bay. The site is one of a series of coastal caves and rock shelters at Pinnacle Point that has preserved detailed archives of human occupation and climatic and environmental changes spanning the Middle and Late Pleistocene (Bar-Matthews et al., 2010; Brown et al., 2009, 2012; Marean, 2010; Marean et al., 2004; Matthews et al., 2011) (Fig. 1). Sediments have incrementally built up at the base of the cliff in front of PP5-6 since the Last Interglacial high sea stand, ~125,000 years ago, and the preserved sediment stack is now ~30 m tall. Detailed descriptions of these sediments and our excavation methodology can be found in Brown et al. (2012) and Karkanas et al. (In Press).

Excavations into the sediment stack have revealed periods of predominantly Aeolian activity, rock fall, fluvial activity, human occupations, and other natural processes. However, at the base of the stack, a ~5 m tall by ~5 m wide natural truncation of the hillslope has provided the largest continuous stratigraphic section at the site (Supplementary Material). This section is called the "s848 profile" owing to the southing line that the profile intersects perpendicularly. Excavations here have revealed a complex yet unusually detailed sedimentological record due to a high sedimentation rate, which has helped to preserve evidence for repeated, short-term occupations at the site as well as subtle and delicate variations in sedimentological features, like stratified hearth deposits.

Besides excavations, the sheer size of the s848 section impeded its analysis and preservation until recently. Of foremost concern was that continued exposure of the entire section would destabilize the wall and most of the overhead sediments. We therefore wanted to document the s848 section as accurately as possible so that we could continue to study it digitally while conserving the original sediments behind a protective buttress of sand bags. However, the subtle differences in sediment color and very fine changes in the sediment texture, roof spall, and anthropogenic materials posed a unique challenge to the photography. Previous attempts to photograph the section failed because we were unable to control the light sources during the daytime, which created unwanted shadows and altered the colors of the sediments between photos. High Definition Range (HDR) photography was able to remove many of the shadows, but the sediment colors remained unreliable. Moreover, the profile was too large to photograph using a conventional tripod.