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The application of a limestone weathering index at churchyards in central Oxford, UK

M.J. Thornbush[a,*], S.E. Thornbush[b,1]

[a] School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK
[b] School of History, Classics and Archaeology, University of Edinburgh, William Robertson Wing, Old Medical School, Teviot Place, Edinburgh EH8 9AG, UK

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ABSTRACT

This study applies a newly introduced weathering scale, namely the size–extent (S–E) index, to limestone markers located in Oxford churchyards. This classification system enables for an assessment of weathering forms based on the consideration of site-specific physical, chemical, and biological types of weathering for central Oxford. Each headstone marker, comprising a legible date, was photographed during fieldwork and the cardinal orientation (aspect) was also recorded. Based on the photographic record of limestone headstone faces, it was possible to apply the S–E index in this cross-disciplinary study. Past applications of (semiquantitative) weathering scales focused on marble headstone markers and were based on the dissolution of inscriptions, and detailed criticisms are provided. The S–E index provides a broader classification of weathering processes based on visible surface forms. It also provided a basis to ascertain that there were more west-facing headstones (than east-facing) that were weathered. The study is a contribution to archaeogeomorphological research.

Introduction

Geography can be applied as part of geomorphology to investigate cultural problems particularly associated with tangible heritage. More specifically, through the deliberation of the conservation of material culture, it is possible to effectively integrate physical geography within an applied approach in the discipline. Weathering studies are especially relevant here to examine the soiling and decay of cultural stoneworks. Techniques employed by geomorphologists in weathering studies are useful for assessments of the current condition of the cultural record. These assessments, such as weathering scales/indices, could either qualitatively or quantitatively assess the state of cultural monuments, such as headstones. By producing a seriation of dated headstones, for instance, it is possible to track cross-temporal change at specific locations (e.g. urban churchyards). Cross-temporal trends may be used to assess the historical record of air pollution and its impact on the environment. When weathering is considered, however, more than atmospheric pollution must be taken into account and microclimate as well as other factors should be implicated in rock weathering. This multivariate approach has been endorsed by many weathering scientists and presents a genuine application of geography (physical geography: geomorphology) in the conservation of cultural heritage.

Pope, Meierding, and Paradise (2002) considered the weathering of "cultural stone", with geomorphologists taking a systems approach driven by processes at rates controlled by thresholds. They acknowledged the significance of biological and chemical weathering through biota and saline agents of weathering as well as climatic impacts associated with exposure (microclimate) and human impacts. The authors encouraged a continued collaboration in cultural stone weathering studies between geomorphologists, conservators, archaeologists, and engineers. Butzer (2008) more recently argued for an address of urban and architectural sites, which are less familiar as part of geoarchaeology.

Much work has been conducted by Meierding on the weathering of (marble) headstones, particularly in the USA. He established an inscription-based legibility method for discerning the rates of rock weathering (Meierding, 1993). In this paper, he treated headstones as any landform examined by geomorphologists, relaying that (at the time) few geomorphologists and other scientists studied their weathering. Headstones presented an opportunity for assessing cross-temporal landscape change (and weathering rates) because of names and dates actually carved into monuments, buildings, and other cultural stoneworks. Taking this approach, he sought to establish a transfer function of relative inscription legibility that would reveal the rates of rock surface recession. Previous studies used other means of measuring surface

* Corresponding author. Tel.: +44 (0) 121 414 8143; fax: +44 (0) 121 414 5528.
E-mail addresses: m.thornbush@bham.ac.uk (M.J. Thornbush), s.e.thornbush@sms.ed.ac.uk (S.E. Thornbush).
[1] Tel.: +44 (0) 131 650 6693; fax: +44 (0) 131 651 3070.

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recession rates, including lead plugs (e.g., Dragovich, 1986; Sharp et al., 1982) and unweathered stone surfaces near the ground (Feddema & Meierding, 1987; Meierding, 1981).

One of the earliest (semiquantitative) attempts to use inscription legibility as a visual indication of stone deterioration was by Geike (1880), who estimated 15 years for the legibility of marble pillar inscriptions on tombstones (headstones) for a polluted environment like Edinburgh, where many headstones exposed in such an atmosphere after 80 years had become completely illegible. Similarly, Julien (1883) discovered that marble headstones in urban Manhattan, NY retained their polish for 10 years and some one-tenth of century-old inscriptions were illegible. He also alluded to the influence of weathering in the conservation of monuments, as of Mayan limestone monuments (Dragovich, 1980). In addition to other authors, who quantified rock surface recession rates based on inscription legibility (e.g., Emery, 1941; Matthias, 1967), Rahn (1971) used a descriptive (qualitative) six-class ordinal legibility scale and applied it to four stone types (granite, schist, marble, and sandstone) in New England. This legibility scale was subsequently employed on marble headstones by Meierding (1981), who discovered (for seven cemeteries) the impact of rainfall on legibility, with less legible inscriptions in the eastern USA, which has a rainy climate compared with the arid west.

The emphasis has been on the weathering of marble (as a harder rock type) rather than limestone. There are several possible reasons for this, including the greater abundance of marble headstones in North American cemeteries; for instance, Bauer, Hannibal, Hanson, and Elmore (2002) uncovered a conversion from sandstone to marble (by the 1830s) followed by granite (in the late 1800s). A diversification of rock type was particularly evident in two country churchyards since 1950 (Dove, 1992). As well, it could be that it was simpler to focus on one type of weathering (chemical weathering), as found in dissolution studies of headstones. For instance, Dragovich (1981, 1986), Feddema and Meierding (1987), Neil (1989), and Guidobaldi and Mecchi (1993) have all investigated the weathering of marble, including specifically the dissolution of Carrara marble gravestones in the UK (Hoke & Turcotte, 2004). More recently, Meierding (2000) probed the effect of surface lowering (as of upward-facing slabs) and suggested that this happens due to rainfall acidity (dissolution of calcite by acids occurring in precipitation). Dragovich (1997) similarly considered headstone inclination (in addition to orientation, comparing seaward-facing stones versus landward-facing headstones), finding that stones emplaced at a low angle (regardless of orientation) weathered faster than more upright (vertical) headstones. Cooke, Inkpen, and Wiggs (1995) also considered the effects of rainfall and pollution at three different sites in the UK.

Research into the weathering of sandstone and limestone headstones has been relatively neglected because of the emphasis on marble headstones to establish surface recession rates; for instance, Matthias (1967) produced one of the few studies on Portland arkose headstones; Wells, Hancock, and Fryer (2008) also examined the weathering of sandstone headstones. In addition, Williams and Robinson (2000) conducted much work into headstone weathering, including that of the effects of aspect on the weathering of sandstone headstones located in south-east England. Nevertheless, some studies addressed limestone weathering specifically on headstones, including Goodchild (1890), who examined their weathering rates; Sweeting (1966) studied the Carboniferous limestones of northern England; Klein (1984) for Haifa, Israel; Sharp et al. (1982); as well as Trudgill et al. (1991) and others, who investigated St Paul's Cathedral in London, UK. Fitzner, Heinrichs, and La Bouchardiere (2003) assessed the weathering damage of Pharaonic sandstone monuments in Luxor, Egypt.

Research in this area within headstone studies has been mostly quantitative (or semiquantitative) because of the emphasis on establishing surface recession rates. Geochemical studies, for instance, have contributed to this quantitative assessment (e.g., Cassar & Vella, 2003; Reddy, 1988; Rogner, 1988). Meierding (1993) himself established an inscription legibility technique based on Rahn's (qualitative) ordinal legibility scale, but with the inclusion of 12 distinct classes pictorially portrayed in his Fig. 1 (p. 276). Such approaches in weathering surveys remained fixated on dissolution, since they aimed to quantify the rate of surface recession. In so doing, they ignored other types of weathering besides dissolution, which is only one kind of (chemical) weathering. Thornbush (2009), for instance, presented the three main components of the weathering process, namely mechanical or physical, chemical, and biological weathering.

Thornbush's (2012a) more recent publication introduced a new classification scheme, the size–extent (S–E) index, based on a tiered five-point index, with scores ranging between two and six. The S–E index (appearing in her Fig. 1, p. 280) captured weathering forms at the micro- to mesoscale in range or size (S1–4) and at two levels of low (E1) to high (E2) extent. Flora and fauna are considered in the classification, where lower scores represented small discrete features and higher scores represented larger weathering forms that could be extensive. The index has potential to be semi-quantitative, and this will be the emphasis of the application in this paper.

The purpose of this paper is two-fold: to test a recently introduced weathering index, namely the S–E index, to examine a cultural resource (other than historical buildings); and to present it as an example of an archaeogeomorphological study that is based on a weathering assessment of material culture. The S–E index was already presented by Thornbush (2012a) for historical buildings along Queen's Lane in central Oxford, UK. It is applied here to other cultural heritage, this time of headstones contained in churchyards located in the city centre. The ambition here is to further develop and improve it as an assessment tool that has potential as a semi-quantitative instrument that can be employed in cross-disciplinary research, as in this study. Here, the physical environment (slabs of limestone) contained in four local churchyards are examined for their level (or degree) of conservation in terms of their weathering condition. The idea is to assess the cultural record from a physical-science perspective (of weathering science) that is diverse and holistic, considering all aspects of weathering, including physical/mechanical, chemical, and biological types. As a cross-disciplinary collaboration between a geomorphologist and archaeologist, this study represents an evolving subdisciplinary approach, as addressed recently in this journal by Thornbush (2012b), in

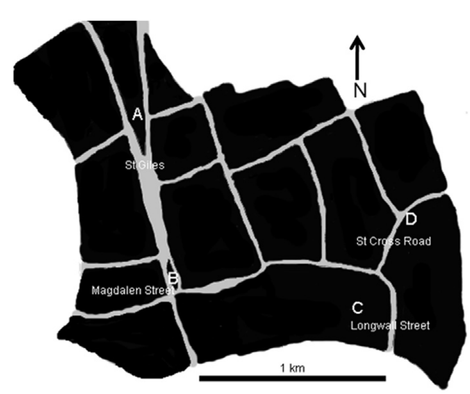

Fig. 1. Map of the study area, showing the location of the four Oxford churchyards in this study: A) St Giles's; B) St Mary Magdalen; C) St Peter-in-the-East; and D) St Cross.