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Key Words

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Mini Review

Environments of Glass Patination in Western Australia

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Abstract

Patina on ancient glass holds potential to interpreting formative environments climatically, pedogenically, hydrologically, hydro chemically, and biologically and, in more recent times, has the potential to interpreting sub-recent formative environments. In addition to experimental information, if patina is to be used as reliable indicators of past environmental conditions, there also needs to be a systematic examination of its development under a variety of field-oriented conditions using varying glass types, i.e., various climate and soil types. We believe that it is useful to document the weathering effects on glass under a variety of field conditions, and this paper focuses on the range of patination in different environmental settings.

Introduction

Glass is one of the most ubiquitous of artefacts occurring in historical archaeological sites, and is also common in modern environments. When weathered, glass commonly is coated with a patina that is a thin to ultra-thin crust that forms on its outer surface [1] (Figure 1), the build-up of which can be used as a baseline for calibrating patina-forming processes, determining the age of patina, and reconstructing patina-forming palaeo-environments [2]. It is this patina that is the focus of this paper. Figure 2 illustrates the complexities in micro-structures, patinelles (for definition, see later), composition, and patination history that can face researchers of patina. Corrosion also is a feature of the weathering of glass, but this will be the subject of a later paper. Figure 3 illustrates the patina developed on marine-submerged glass offshore from the Zuytdorp Cliffs.

Figure 1: Heavily patinated glass bottle from a terrestrial environment at Port Hedland.

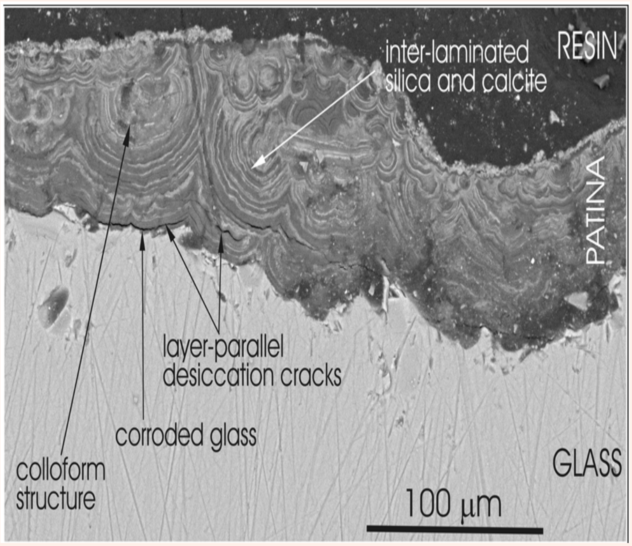

Figure 2: Crust of patina on glass showing a selected range of microstructures. Prominent here is the corroded contact between patina and glass, colloform structures, the interlamination of silica (medium grey) and calcite (light grey), and layer-parallel desiccation cracks (thin black lines).

Figure 3: Heavily patinated glass from a submerged marine environment, Zuytdorp Cliffs (sample is approximately 4 cm long).

In fact, glass is chemically metastable and, depending on glass type, climate setting, micro-climate fluctuations, soil chemistry, water chemistry, extent of temporal interaction with water, and biotic influences will undergo alteration in this variety of environments [2-7] resulting in corrosion phenomena, or in (downwards) accretionary patina. As such, patina holds potential to record these environmental conditions and changes in environmental settings as expressed in its internal structures, micro-lithologies, and post-patination features. To calibrate and interpret the age of patina, processes of its development, and micro-products of its formation in addition to experimental development of patina [2], we believe that it is useful to document patina on glass under varying environmental conditions ranging from tropical to temperate climates, humid to arid climates, and in a variety of edaphic settings. That is, if patina is to be used as a reliable indicator of age and environmental conditions underpinning its formation, there needs to be a systematic examination and understanding of its development with varying glass types, climate types, and soil types.

The aim of this paper, therefore, is to describe the range of environments we have studied that have formed patina on glass-such results would be useful in archaeology and palaeo-climatology for determining glass burial age, climate changes and the former pedogenic and hydro chemical setting of patinated glass. As such, we undertook study of patina on glass collected from ten different climatic and environmental study sites (Figure 4). The range of terms used in this paper is defined in Table 1. The range of environmental features of the study sites (viz., climate, soils, terrestrial versus aquatic setting, etc.) are described in Table 2.

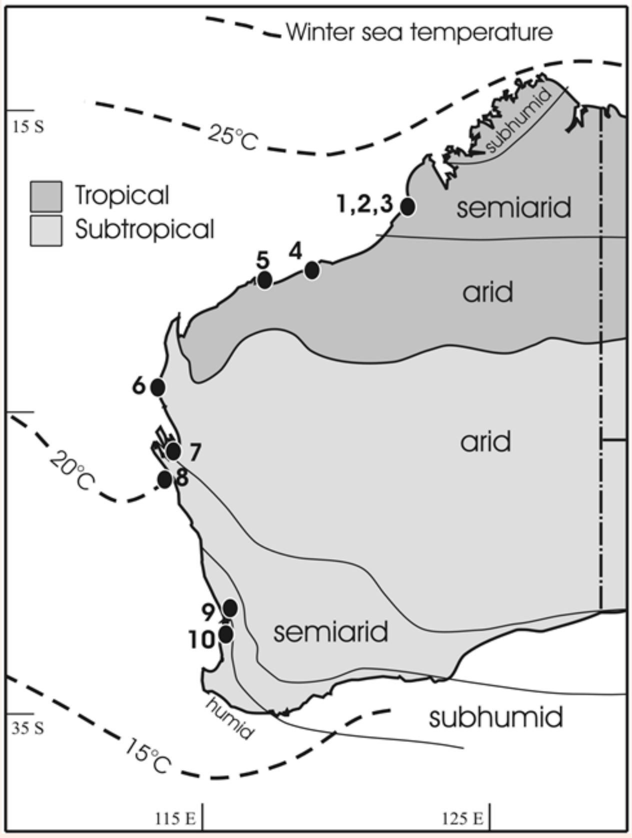

Figure 4: Location of the ten samples used in this study in relation to climate zones (see also Table 2). Climate map from Semeniuk et al. [8].

Table 1: Terms for the description of patina and its internal structures (illustrations of these can be found in Clifford & Semeniuk [2].

Term	Description
brecciated glass	brecciated glass
colloform laminae	structure or micro-structure of finely spaced, undulating to hemispheric layering simulating a cross-section of a cabbage-like structure
curvilinear and curved invasive fronts	solution invasion front that is broadly curvilinear (curved)
cusps, scallops on surface of glass	cusps are small-scale triangular, 'tooth-like' projections on the surface of glass at the patina/glass contact; scallops are small-scale, curvilinear, broadly u-shaped dissolutional surfaces
fungal micro-borings	tubular micro-borings produced by fungi
invagination	deeply penetrating embayments occurring as 'finger-like' intrusions into the glass
patina	a thin weathering crust on the surface of a glass; the patina may be micro-structurally and/or compositionally complex (cf., patinelle)
patinelle	a term, coined by Clifford & Semeniuk (2020), for the smaller-scale, discrete structurally- and/or compositionally-distinct components of a patina
pitting	microscale solutional holes on the surface of the glass at the glass/patina contact
micro-breccia in patina	patinelle comprised of angular fragments in a matrix of finer-grained material
micro-unconformities	the geometric inter-relationships of the various types of patina, patinelles, and the various layers of patina, and their relationship to the parent glass showing angularity of contact, simulating stratigraphic relationships commonly found in Geology
massive, structureless patinelles	massive, structureless patinelle usually of fine-grained silica
matched-sided shrinkage cracks	matched-sided shrinkage cracks
mottled patina	irregular to equant patches composed of fine-grained silica, each patch of a slightly different grainsize and/or tonality
parallel laminated patina	structure or micro-structure comprised of finely spaced, parallel layering, usually of silica but may be alternating silica and calcite
shrinkage cracks	shrinkage cracks

Table 2: Occurrence of patinated glass with respect to climate and local environmental setting ordered from north to south (locations are shown in Figure 4).

Patinated Glass Location	Description of Climate and Environment
1. Broome	tropical semi-arid climate, supratidal, terrestrial, stranded carbonate flat
2. Broome	tropical semi-arid climate, terrestrial, dunal quartz/carbonate sand
3. Broome	tropical semi-arid climate, terrestrial, dunal quartz/carbonate sand
4. Port Hedland	tropical arid climate, terrestrial, dunal quartz/carbonate sand
5. Cossack	tropical arid climate, terrestrial, dunal quartz/carbonate sand
6. Quobba	subtropical arid climate, coastal elevated supratidal limestone pavement subject to ocean mist and storm-level spray
7. Shark Bay	subtropical arid climate, supratidal, terrestrial, stranded carbonate flat
8. offshore Zuytdorp Cliffs	subtropical arid climate, marine subaqueous (shipwreck)
9. Lake Gwelup	subtropical humid climate, terrestrial, stranded wetland margin of peaty quartzose sediments
10. Mandurah	subtropical humid climate, terrestrial, subaqueous peaty wetland sediment

The Range of Patination Processes and Products

As patina develops over time, there is a range of micro-structures and chemical features that are produced. These result from the dissolution of glass (producing corrosion features, and liberating silica as solute), micro-borings by fungi, precipitation of silica as a gel as laminae and as cavity fills, shrinkage of the silica gel to produce laminae-parallel laminoid shrinkage cracks, shrinkage of the silica gel to produce micro-hexagonal cracking within the laminae, re-solution of the precipitated silica, dissolution of the carbonate grains and its reprecipitation as calcite laminae (depending on the carbonate content of the enclosing sediment matrix), brecciation of the laminae (to produce micro-breccias). As such, there are primary patina features and, with age, precipitation, dissolution, and re-precipitation, there are secondary and tertiary patina features. Three levels of patination are described: 1. the occurrence of patinated glass with respect to climate; 2. the environmental setting of patina; and 2. more detailed description of the patina using SEM [2].

The Occurrence of Patina with Respect to Climate, and Local Environmental Setting

Much of Western Australia was colonized in near-coastal zones and, as such, refuse sites containing glass are commonly in coastal or near-coastal settings. Figure 3 shows the sampling location of patinated glass used in this paper distributed along the coast. Figure 3 also illustrates the climate setting of the samples. Patinated glass also has been found in a wide variety of environments, from arid coastal sands to humid climate coastal sands, to wetlands, to coastal limestone elevated platforms, to stranded (prograded) coastal plains. It has also been found as submerged artefacts in shipwrecks (e.g., the Zuytdorp wreck offshore from the Zuytdorp Cliffs). Table 2 summarises the occurrence of patinated glass with respect to the variety of climate settings and local environmental setting.

It can be seen from Table 2 that patination of glass occurs in a range of climatic and environmental settings, ranging from maritime cliff-tops, dunes, to tidal flats, to wetlands, to submerged marine environments. Details of how these climatic and environmental settings determine details of patination and patinelle formation will be the subject of a later paper. More detailed description of the patina using SEM is provided in Clifford & Semeniuk [2].

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