

1981/26. Clay fraction mineralogy of Triassic sandstones from Port Arthur and comparison with other rocks for building restoration.

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Abstract

The clay fraction ($<2 \mu\text{m}$) in the matrices of Triassic, fresh-water sandstones from Port Arthur contain variable amounts of a probable mixed layer montmorillonite-illite. The swelling nature and enhanced cation exchange properties of this clay may render the stone unsuitable for use in buildings subject to salt attack by capillary action, evaporation and water movement.

INTRODUCTION

In May 1980, the mineralogical services of the Department of Mines were offered to the National Parks and Wildlife Service in order to facilitate selection of suitable rocks for restoration of the buildings at Port Arthur. Subsequently P.E. Spratt of England, Newton, Spratt and Murphy Pty Ltd, consultants on this project, arranged for suitable rocks to be collected as part of their programme for determining the stability of the sandstones under salt attack. A series of other sandstones, some from interstate sources, were tested at the same time for comparative purposes.

The Port Arthur area has been mapped by Cromer *et al.* (1976) and a report on the sources of building stone made by Cromer (1976). The mineralogy of the sandstones is briefly discussed in reports by Roberts (1976, 1977) but more attention has focussed on the mineralogy of bricks made at Port Arthur (Crawford de Bavay and Cripps, 1979). The present report aims to identify those sandstones which are unsuitable for reconstruction by virtue of their susceptibility to environmental attack and rapid disintegration. The environmental factors identified by P.E. Spratt (in Crawford de Bavay and Cripps, 1979) are salt, water and evaporation.

EXPERIMENTAL TECHNIQUES

The techniques employed were those recommended by Dorothy Carroll (1970), *i.e.* disaggregation (in tap water), sedimentation of the sand and silt fractions, and preparation of an oriented mount of the clay fraction ($<2 \mu\text{m}$) in order to identify basal spacings (00 ℓ) of clays forming the sandstone matrix.

X-ray diffraction scans over the range $4 - 29^{\circ}2\theta$ were made and where a $\sim 14\text{\AA}$ diffraction peak was found, glycolation under reduced pressure (or slight heat) was carried out to confirm the identification of a montmorillonoid type clay.

Samples are processed at the rate of about one per hour, including a preliminary X-ray diffraction scan. Thin sections of some of the samples have been prepared but it is difficult to improve on the description made by G. Everard (in Cromer *et al.*, 1976), where the cement in a quartz sandstone is described as of 'sericitic and clay minerals stained with limonite'.

RESULTS

Table 1 lists the data obtained by X-ray diffraction scans. Three samples are from Port Arthur, identified as: 1. Larner's Quarry, Safety Cove (quarry 3 of Cromer, 1976) EN683185; 2. Plummer's Quarry (quarry

1 of Cromer et al., 1976) EN682224; and 3. Briggs' Quarry (quarry 2 of Cromer et al., 1976) EN680213. A block of sandstone from the Anglesea Barracks (BA2) and eleven sandstones identified only by letters and which were thought suitable for replacement were also tested. Two samples of clay from the foundations beneath the Chaplain's and Overseer's huts were treated by the same methods. Diffractograms of the Port Arthur and Anglesea Barracks samples and clay from the foundations of the Chaplain's cottage are included as Figures 1-3.

The British term 'smectite' may be preferable to the more specific North American term 'montmorillonite' but precise nomenclature awaits detailed chemical analyses and determination of the nature of the probable mixed-layering.

In general, the clays in the sandstones are poorly crystallised and give rather broad diffraction peaks. The most friable sandstones are those containing smectite (montmorillonite), even in small amounts; sample C, containing kaolin alone, is also friable. All the sandstones examined are quartz sandstones with a grain size of 100 - 400 µm and generally less than 10% lithic fragments. Feldspar grains form less than 5% of the samples and the amount of matrix (cement) forms from 1 to 10% of the thin sections. This range corresponds approximately to the range 'very low clay' to 'high clay' in Table 1.

The clay fraction separated from sandstone at Plummer's Quarry (No. 2, Table 1) at Port Arthur was examined by electron microprobe. A semiquantitative chemical analysis confirmed the montmorillonoid mineral to be a mixed layer clay, i.e. montmorillonite-illite. The montmorillonite (*sensu lato*) has both Al for Si substitution in the tetrahedral sites (beidellite) and Fe in octahedral co-ordination (nontronite); a random interlayering of illite is suggested by values of 1 - 2.5% K₂O. A more sophisticated analysis of the montmorillonite will require chemical analysis and randomly oriented X-ray diffraction, both beyond the immediate scope of this report. During microprobe analysis, the heavy mineral content of the sandstone was confirmed as due to ilmenite and rutile/leucoxene.

INTERPRETATION

The occurrence of montmorillonoid type clays in the Triassic, non-marine sandstones is not unexpected in view of the mounting evidence of volcanic activity in the Triassic, dating back to Lewis and Voisey (1938) and more recently, Bacon and Everard (1981) for example. It was suspected in the dirt bands of Triassic coal seams by Threader (1981, pers. comm.).

Montmorillonoids are commonly thought to be absent from sediments older than Mesozoic with the exception of bentonites. However, the abundance of interlayered montmorillonoids in ancient sediments is not only a function of geographic distribution of volcanic material but implies the occurrence of fresh water and alkaline conditions. Mixed layer illite-montmorillonites are a common diagenetic development in water of low ionic strength as a result of the partial collapse of montmorillonite structure originally derived from volcanic glass. It appears that the complete transformation of montmorillonoids to illite and chlorite in the marine environment following adsorption of potassium and magnesium, respectively, is inhibited in fresh water sediments (Grim, 1968) while kaolinite is a clear indicator of continental origin. Inspection of Table 1 confirms the general view (e.g. Perrin, 1971) that smectites (montmorillonoids) and kaolinite are antipathetic. This provides a strong indication of a volcanic origin. It is uncertain whether the illite in these samples is formed from

Table 1. MINERALOGY OF CLAY MATRIX, SANDSTONES, PORT ARTHUR

Sample	XRD scan (glycolated)		Mineralogy, <2 μ m fraction	Remarks (including clay content †)
<i>Sandstones</i>				
1. Larners	+	+	Mont.,* Qtz.*	Low clay, Fe fluorescence friable
2. Plummers	+	+	Mont.>Illite> Kaolin minor Qtz.	High clay, Fe fluorescence, very friable
3. Briggs	+	+	Mont.>Illite, Qtz.	Moderate clay, slight Fe fluorescence, friable.
4. Anglesea Barracks	+	+	Mont.>Illite, minor Qtz.	Low clay, friable
5. A¶	+	-	Illite, Qtz.	Very low clay
6. B¶	+	-	Illite>Kaolinite, minor Qtz. (both well crystallised)	High clay
7. C¶	+	-	Kaolin, Qtz.	Low-moderate clay, friable
8. D¶	+	-	Illite>Kaolin, Qtz.	Moderate clay
9. E¶	+	-	Illite, Qtz.	Very low clay
10. D1¶	+	-	Kaolin>Illite, Qtz.	Low clay
11. D2¶	+	-	Kaolin>Illite, Qtz.	Low clay
12. D3¶	+	-	Kaolin>Illite, Qtz.	Very low clay
13. D4¶	+	-	Kaolin>Illite, Qtz.	Low clay
14. R1¶	+	-	Kaolin>Illite, Qtz.	Low-moderate clay
15. R2¶	+	-	Kaolin>Illite, Qtz.	Low clay
<i>Clays</i>				
16. Chaplain's Cottage	+	-	Kaolin +~15% Mont., minor Qtz.	Silt, sand removed in preparation, Fe fluorescence
17. Overseer's Cottage	+	-	Kaolin +~5% Mont., minor Qtz.	Silt, sand removed in preparation

* Mont. = montmorillonoid type clay, Qtz = quartz

† Clay content determined by peak height and consideration of amount of sandstone processed to yield sufficient clay for an X-ray diffraction mount.

¶ Location not specified.

mechanically degraded, detrital, dioctahedral micas or whether it is a product of absorption of potassium during diagenesis of the clay-size fraction; possibly both origins are involved.

Much has been written on the problem of cation or base exchange as it affects the building materials at Port Arthur (Roberts, 1976, 1977; Cole, 1975). The redistribution of soluble salts, crystallisation, subflorescence and the disruption of rock fabric by crystallisation are well described in section 6.01.03 of Crawford de Bavay and Cripps (1979, vol. 1) and in the technical appendices. Not only does cation exchange modify the composition of the clay minerals involved but the composition of the groundwater itself is changed as it permeates the building fabric. The reaction $K^+ \text{ clay} + NaCl \rightarrow Na^+ \text{ clay} + K^+ Cl^-$, tested on the underfired bricks (Roberts and Kallend, 1976), may be a source of K^+ ions for further degradation of the montmorillonoid component of the mixed layer clay. It should be noted that if a montmorillonoid is treated with an equimolar solution of a K and Na salt, much more K^+ than Na^+ will be absorbed. The high cation exchange capacity of montmorillonoids (80 - 150 meq/100 g) compared with kaolinite (3 - 15 meq/100 g) and illite (10 - 40 meq/100 g) undoubtedly contributes to the formation of soluble salts and subsequent mechanical breakdown of the sandstones.

It is desirable that sandstone with the lowest clay content be sought when replacement stone is required for renovation but experience in this project suggests that even if the matrix clay content is described as low, i.e. about 1 - 2%, the occurrence of a montmorillonoid (swelling) clay may make the stone a poor choice under severe environmental conditions. In these circumstances it could be necessary to use stone from non-local sources such as samples 5, 9, 10-13 (Table 1). Sample 7, containing kaolin alone in the matrix, is not recommended.

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[24 April 1981]

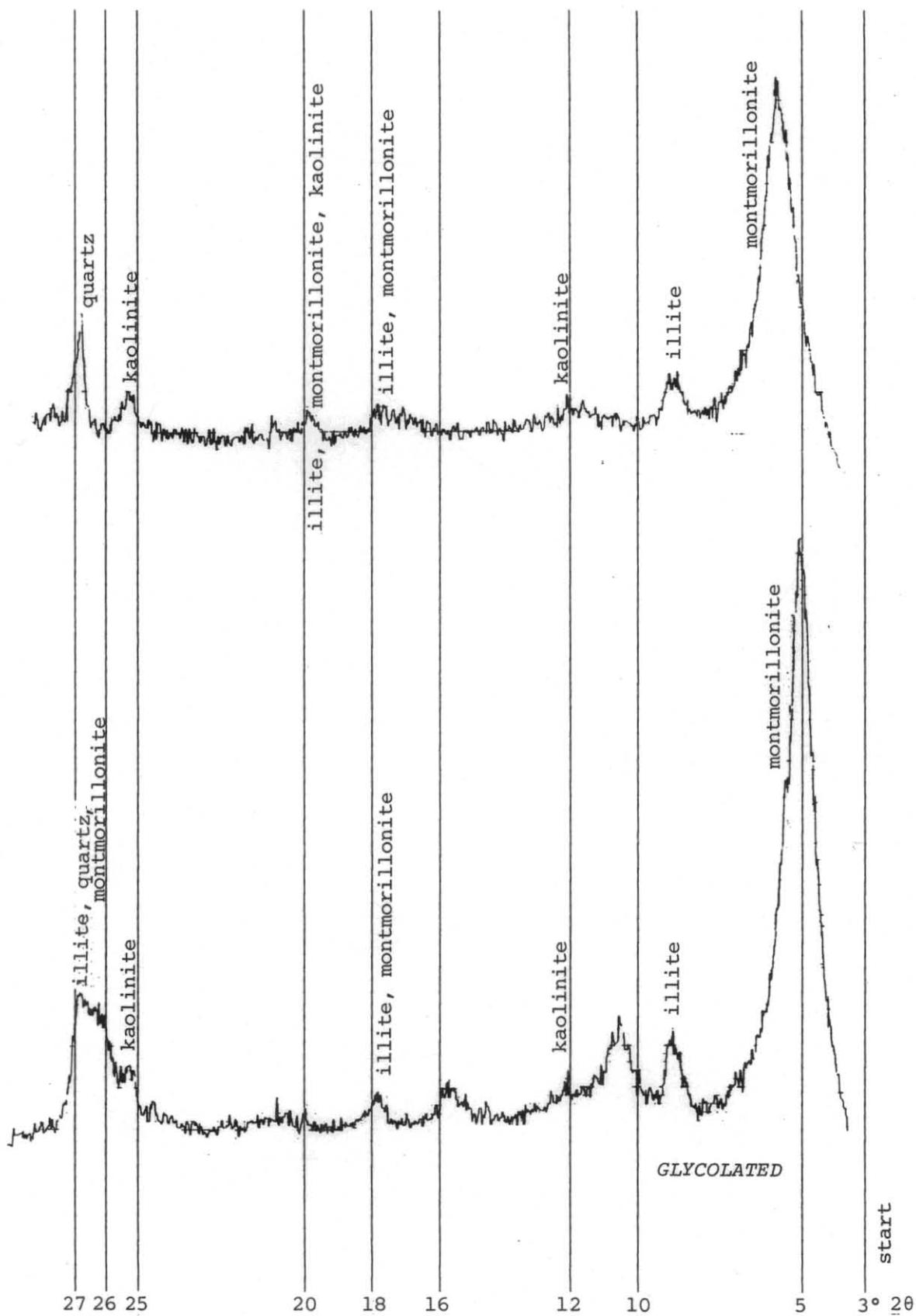


Figure 1. Diffractograms of sample 2, sandstone from Plummer's quarry, Port Arthur.

5 cm

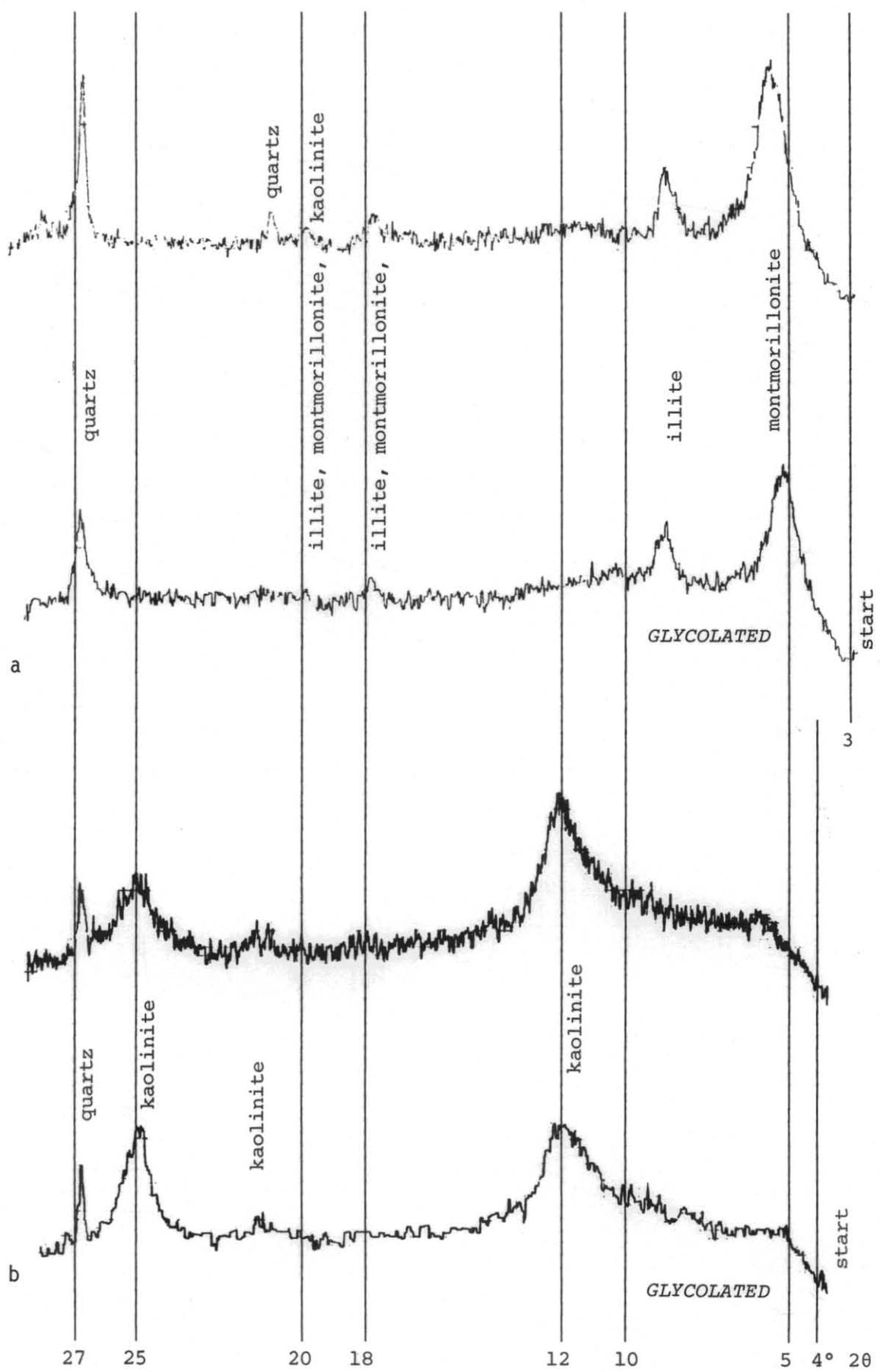
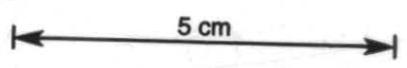


Figure 2. Diffractograms of (a) Sample 3, sandstone from Briggs' quarry, and (b) Sample 16, clay from the Chaplain's Cottage, Port Arthur.



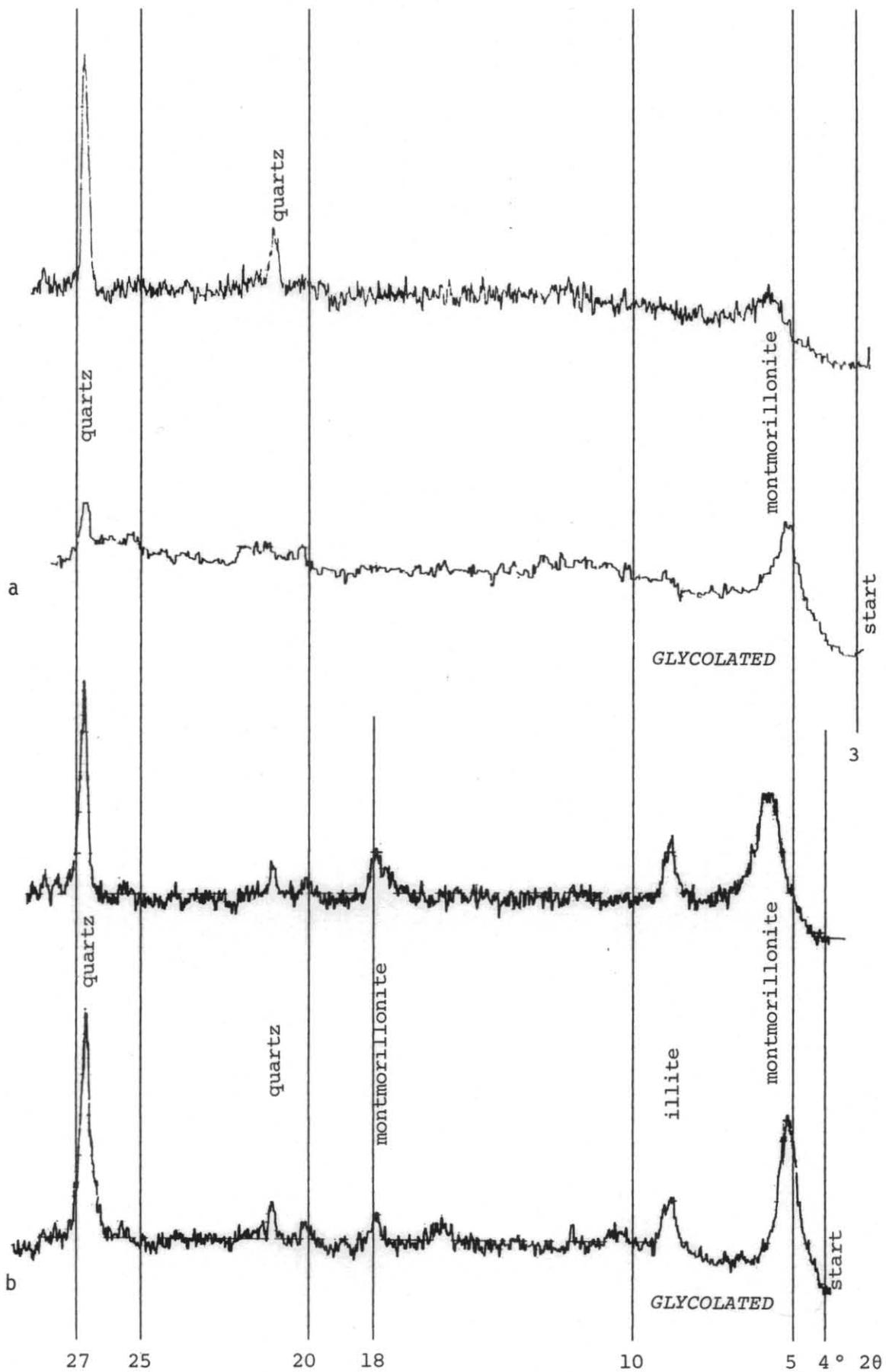


Figure 3. Diffractograms of (a) Sample 1, sandstone from Lerner's quarry, Port Arthur, and (b) Sample 4, sandstone from Anglesea Barracks, Hobart.