

**Petrology, XRD and SEM of Sidewall Cores from
Koorkah 1**

OR-0290



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Attention: Steven Bane

REPORT F 6363/86

YOUR REFERENCE: Telex 7 January 1986, D/No. 1060

MATERIAL: Sidewall cores

LOCALITY: Koorkah-1

DATE RECEIVED: 7 January 1986

WORK REQUIRED: Thin section petrography, X-ray
X-ray diffraction and scanning
electron microscopy

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1. INTRODUCTION

Nine sidewall core samples from Koorkah-1 were received for thin section petrography, X-ray diffraction and scanning electron microscopy.

The results of this study were reported by facsimile (10 January 1986) together with preliminary interpretative comments. This report is a formal presentation of this data.

2. ANALYTICAL PROCEDURE

2.1 Thin Section Petrography

A portion of each sample was vacuum impregnated with epoxy resin to aid in the identification of pore spaces in the sandstones. Thin sections were then prepared by standard procedures and examined using plane polarised light and crossed Nicols.

2.2 X-ray Diffraction

The samples were air-dried at room temperature. A portion of each sample was powdered finely and used to prepare an X-ray diffractometer trace which was interpreted by standard procedures.

Weighed subsamples were taken and dispersed in water (with the aid of deflocculants and an electric blender) and allowed to sediment to produce $-2 \mu\text{m}$ e.s.d. size fractions by the pipette method. The resulting dispersions were examined by plummet balance to determine their solids contents, and were then used to produce oriented clay preparations on ceramic plates. Two plates were prepared per sample, both being saturated with Mg^{++} ions, and one in addition being treated with glycerol. When air-dry, these plates were analysed in the X-ray diffractometer. Additional diagnostic examinations carried out consisted of examination of the glycerol-free plate after heating for one hour at 550°C .

2.3 Scanning Electron Microscopy

A fresh portion of each sidewall core was mounted on a metal stub and coated with carbon, and a gold/paladium alloy. The sample was examined using an Etec SEM equipped with an energy dispersive X-ray analysis system.

3. RESULT

3.1 Thin Section Petrography

Petrographic descriptions of each thin section are presented below. A series of plates illustrating these descriptions is included in Appendix 1.

PETROGRAPHY

The samples examined were sections cut from sidewall cores and, as is commonly the case, some reservations are necessary when interpreting the petrology. These reservations stem from problems relating to disturbance of the sandstone during collection of the sidewall core and also during preparation of the thin section. Some of the rigid detrital material may be fractured during these processes but, even more important, some of the intergranular softer material is lost or disturbed. In addition there may be some entry of drilling fluid into the intergranular spaces.

Sample: TSC46776; Location: Koorkah-1, 1615.5 m

Rock Name:

Porous sandstone

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz	70
Pores	15
Clay matrix	10-15
Authigenic kaolinite	1
Mica	Trace
Heavy minerals	Trace

The quartz grains in this sandstone range up to approximately 1 mm in size but the largest grains probably represent a rather small population amongst material which is moderately sorted about an average size of approximately 0.3 mm. Many of the quartz grains show excellent rounding but there are some places in the thin section where there is some development of long contacts and, due to post depositional effects, the grains are more angular. The minor detrital constituents are a little muscovite and rare grains of tourmaline and zircon. Feldspar is apparently absent.

The extent to which the clay matrix is derived from original lithic fragments is difficult to determine with any confidence but it seems likely that possibly somewhere within the range of 10 to 40% of the clay was formed in this fashion. Elsewhere, the clay matrix is generally more or less brown in colour and some appears to be chloritic material. There are a few patches of rather porous authigenic kaolinite and some of these are as much as 0.2 mm in size. Only where the clay can be positively related to detrital-lithic fragments does it form any contiguous or compact patches; otherwise, the clay is present as fine-grained patchy material and forms on grain surfaces or as loose aggregates within intergranular spaces.

As a result of this patchy distribution of the clay the sample has a considerable porosity but few of the pores are clean, quartz-bounded intergranular spaces; most are rather small in size and are associated with porous clay material.

Sample: TSC46775; Location: Koorkah-1, 2070 m

Rock Name:

Porous sandstone

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz	65
Pores	30
Clay matrix	2
Mica	1
Feldspar	1
Lithic fragments	1
Carbonate	1
Heavy minerals	Trace

This is an extremely loose and porous sandstone in which approximately $\frac{1}{3}$ of the area of the thin section consists of relatively large and certainly well interconnected primary pores. Intergranular material is confined to aggregates similar in size to the detrital grains but, as the list above shows, these are not abundant.

The quartz grains are moderately well-sorted about an average size of approximately 0.15 mm. The grains range from well rounded varieties to subangular grains. Some of the latter have been effected by post depositional marginal dissolution but it is likely that this process has occurred only to a small extent and has contributed little to the occlusion of the original porosity. One or two of the detrital grains are slightly turbid and show no twinning and these are interpreted as being potassium feldspar. As well as this mineral there are trace amounts of detrital muscovite and a range of tourmaline types including some unusual blue varieties.

The most noticeable feature of the intergranular material is its patchy distribution. Typical low magnification fields of view contain three or four aggregates of more or less turbid or brown material and these tend to be of the order of 0.2 to 0.3 mm in size. Some of the more deep brown coloured aggregates which have a dark colour between crossed Nicols may be drilling mud but the presence in some of them of what appear to be authigenic carbonate crystals suggests that they may represent a type of lithic fragment widely scattered amongst the sand-grade quartz grains. Other aggregates are definitely derived from lithic fragments in that they consist of fine-grained aggregates of clays and minor quartz. Carbonate is amongst the more abundant of the trace components of the rock and it tends to occur as small polycrystalline aggregates up to 0.3 mm in size. Some of these aggregates may be derived from original limestone fragments which have been recrystallised but elsewhere the carbonate forms small subhedral crystals within clay aggregates and these appear to be late and authigenic in origin. It may well be, therefore, that the carbonate has been introduced into the system.

Sample: TSC46774; Location: koorkah-1, 2135 m

Rock Name:

Porous sandstone

Thin Sections:

An optical estimate of the constituents gives the following:

	%
Quartz	70
Pores	15
Clay matrix	10
Carbonate	1
Mica	1
Authigenic kaolinite	Trace
Feldspar	Trace
Heavy minerals	Trace

There is a range of quartz grain size in this sample commonly from 0.1 mm to about 0.4 mm and in some fields of view the rock appears to be distinctly poorly-sorted. Elsewhere the sorting is somewhat better about an average size of about 0.2 mm. Quartz grains are commonly subround to subangular in shape and there is considerable evidence, particularly amongst the smaller grains, of the development of long and curved contacts. Despite this the rock retains considerable porosity and most of the pores are relatively small and they appear to be of primary origin. Minor detrital phases are potassium feldspar, which is somewhat turbid, and distorted flakes of muscovite. Heavy minerals are represented apparently solely by tourmaline.

The nature of the dark intergranular material which comprises about 10% of the volume of the rock is rather difficult to determine. In plane polarised light much of the material is virtually opaque and it is completely dark between crossed Nicols. There are relatively large patches of this material in one case as much as 1 mm in size but commonly about 0.3 to 0.5 mm. Large aggregates of this dark material appear to have replaced some of the adjacent quartz whereas elsewhere they appear to be distorted and possibly compressed lenses filling the intergranular spaces of the compacted sandstone. The material is sufficiently homogeneous to resemble remnants of an original muddy matrix rather than lithic fragments. The patchy distribution is, on this basis, rather difficult to explain.

There are very small amounts of authigenic kaolinite in the rock but rather more authigenic carbonate. The latter is not staining by alizarin red-S and it forms well defined but rather irregular crystals up to approximately 0.2 mm in size. It seems likely that this is carbonate introduced into the rock at a relatively late stage in its diagenetic history.

Sample: TSC46773; Location: Koorkah-1, 2200 m

Rock Name:

Compact sandstone

Thin Section:

This sample has been extensively damaged during collection of the sidewall core and most quartz grains show brecciation. In many places in the thin section it is not possible to distinguish small grains from broken remnants of original larger detrital grains. The thin section consists of quartz, voids (approximately 5%), traces of zircon and a variable amount of homogeneous brown material interpreted as drilling mud.

Where there is least damage to the rock, quartz grains are mostly 0.15-0.5 mm in size and are fairly common. Thus it is likely that the rock has been lithified essentially by pressure solution effects on quartz. There is evidence of neither clay matrix nor lithic clasts and consequently all the stress would act on the quartz grains initially at the tangential point contacts.

Sample: TSC46772; Location: Koorkah-1, 2602 m

Rock Name:

Compact lithic sandstone

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz	50
Lithic fragments	40-50
Carbonate	3
Pores	2
Mica	1
Feldspar	1
Heavy minerals	Trace

This sample is completely different from those described above in that it contains abundant heterogeneous clay material which is thought to have been derived from an abundant phase of lithic fragments similar in size, and deposited at the same time as, the quartz grains. As a result of compaction effects operating on these relatively plastic detrital clasts, the sample has only a very limited porosity and probably correspondingly low permeability.

Detrital grains of quartz and lithic material appear to have ranged up to about 0.3 mm in size although the average size is approximately 0.1 to 0.15 mm. The quartz grains are equant but rather angular in shape and this is due partly to the nature of the detrital material and, to a small extent, to modifications to the quartz grains which probably occurred relatively early in the compaction and diagenesis of the rock. As well as quartz the detrital material consisted of abundant lithic fragments. These are now represented by a markedly heterogeneous fine-grained phase which occurs throughout the thin section. Some of the material is wholly argillaceous and ranges from almost opaque to colourless clay minerals. As well as these there are fine-grained intergrowths of quartzofeldspathic phases with clay. There are some grains of chert and one or two aggregates of what appears to be possibly opaline silica. It is the heterogeneity of this material which indicates its origin from lithic clasts; it is possible that there is a small amount of original muddy clay matrix but this cannot now be distinguished from the material from lithic fragments. In one or two places there is evidence of discrete fragments having been compressed between the quartz grains but this is not generally the case. A minor phase in the rock is represented by small aggregates of a green clay; these may be glauconite but most appear to have a low birefringence which indicates that they may be somewhat altered or possibly may be a chloritic phase.

There are traces of detrital mica and fresh potassium feldspar and irregular crystals of a late authigenic carbonate which is not stained by alizarin red-S. Pores are confined to very small and irregular features which may not be an integral feature of the rock.

Sample: TSC46771; Location: Koorkah-1, 2757 m

Rock Name:

Compact argillaceous sandstone

Thin Section:

An optical estimate of the constituents gives the following:

	<u>%</u>
Lithic fragments	50
Quartz	25
Carbonate	20
Feldspar	2
Mica	1
Pores	1
Heavy minerals	Trace

The sample is similar to that described immediately above in that it is an extremely tight fine-grained sandstone in which the original detrital material clearly contains very abundant lithic fragments. In this sample, in addition, the rock has been invaded by a considerable amount of authigenic carbonate. Pores are widely disseminated throughout the thin section but tend to be very small and, in many cases, associated with rather porous clay aggregates. It is possible that a considerable proportion of the visible pores result from collection of the sidewall core.

Detrital material appears to have been well-sorted about an average size of approximately 0.15 mm. The quartz and feldspar grains are generally rimmed by clay material and appear to be subangular to subround in shape. There are one or two places where the quartz-to-quartz contacts are long or curved but the abundance of clay appears to have essentially prohibited much modification of the detrital quartz grains during diagenesis.

There is a small amount of fresh potassium feldspar, rare grains of tourmaline and zircon and one or two distorted to somewhat tabular grains of detrital muscovite.

The clay material is similar to that in the sidewall core from 2602 m in that it is decidedly heterogeneous and for the most part consists of essentially monomineralic clay aggregates varying from place to place in the thin section. There are, as well, some aggregates of fine-grained material including quartzofeldspathic phases. As far as can be determined it appears that most of the lithic fragments are of a sedimentary or possibly metasedimentary origin.

The rock contains a large proportion of carbonate which is fairly clear and well crystallised in the thin section although it forms distinctly irregular crystals. Typically these crystals have a poikilitic habit and tend to enclose or partly enclose several grains of quartz and lithic material. More compact crystals of carbonate are generally about 0.1 to 0.2 mm in size. It seems likely that the carbonate is a relatively late mineral and it may well have replaced some types of clay.

Sample: TSC46770; Location: Koorkah-1, 2794.5 m

Rock Name:

Shale with calcareous and lithic sandstone beds

Thin Section:

The thin section consists of about equal amounts of a dark fine-grained sediment which is a shale or shaly siltstone and intercalated irregular beds of a sandstone which contains abundant lithic and carbonate material such as occurs in the sandstone described immediately above. The sample is completely compact and apparently impervious.

The shaly part of the rock is dark mottled brown in plane polarised light but shows some moderate birefringent shades under crossed Nicols. It seems likely that the rock consists of intermixed clay and carbonate with a considerable amount of ferruginous secondary staining. Within this homogeneous dark material there is approximately 20% of identifiable silt-grade clasts. Most of these are equant quartz crystals but there are also large, tabular flakes of muscovite.

The sandstone between these lenses and beds of shaly material is rich in heterogeneous clay material and in authigenic carbonate and these two phases, together with detrital quartz grains, are present in approximately equal amounts. The quartz grains and the clasts of clay material have an average size of about 0.15 mm and appear to have been well-sorted. The quartz grains are compact but generally angular in shape and some of this angularity probably derives from pressure solution effects which occurred during compaction of the rock. The fine-grained aggregates are notably varied and include, as well as argillaceous types, numerous cherty fragments and fine-grained metasedimentary rocks. These fragments have been compressed and distorted between the quartz grains and it is this process which has led to occlusion of any original porosity. As well as this, the sample has also undergone, partial replacement by a late carbonate phase which now forms rather ragged but clear crystals throughout the whole of the rock. Some of these crystals have a poikilitic habit but for the most part they are more or less compact, even though irregular in shape.

The sandstone contains minor detrital heavy minerals, mica and fresh potassium feldspar and there are some discontinuous microstylolitic zones characterised by opaque and semi-opaque ferruginous material.

Sample: TSC46769; Location: Koorkah-1, 2955 m

Rock Name:

Compact argillaceous sandstone

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz	70
Lithic fragments	30
Feldspar	1
Heavy minerals	1
Mica	Trace
Opagues	Trace

Where the rock has not been brecciated during collection of the sidewall core it consists of an impervious aggregate of quartz grains and heterogeneous fine-grained aggregates which are thought to have been derived from original lithic clasts. Both types of material form crystals and aggregates which have an average size of approximately 0.15 mm.

The quartz grains are well-sorted but most are subangular to angular in shape largely as the result of the development of long and curved contacts during compaction. There are rare instances of overgrowths from some of the quartz grains. The rock contains a little more feldspar than many from this well and both plagioclase and potassium feldspar were identified; both types of feldspar show little turbidity and polysynthetic twinning can still be seen in the plagioclase grains. There are small amounts of tourmaline, zircon and muscovite.

The turbid grey material which can be seen in plane polarised light shows many varied textures and mineralogy under crossed Nicols. Some patches of material are birefringent and appear to consist largely of illitic material and there is a range towards monomineralic fine-grained quartz aggregates some of which appear to be cherty in origin whereas others are probably fine-grained sediments or metasediments. Some of the fragments retain evidence of a foliation or bedding direction, others are massive and still others have textural features resulting from squeezing and compression between quartz grains. Some of the more rigid, quartz-rich fragments retain some evidence of a subround outline. All of this material is probably derived from original lithic fragments which were deposited at approximately the same time as the quartz.

Sample: TSC47668; Location: Koorkah-1, 3019 m

Rock Name:

Argillaceous sandstone

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz	60
Lithic fragments	35
Feldspar	2
Mica	1-2
Heavy minerals	1
Carbonate	Trace

This is a somewhat coarser lithic sandstone than most of the others described above and it contains, for example, microcline grains as much as 0.3 mm in size. The average grain size of the quartz and mica fragments is a little difficult to determine because of the fracturing of much of the area of the thin section but many grains appear to be 0.2 to 0.4 mm in diameter. Where quartz grains occur together in small clusters there is considerable evidence of development of long and curved contacts and even triple-point junctions. Elsewhere quartz grains occur singly and abut against patches of clay or other fine-grained material. It appears that compaction and lithification of the rock have occurred both by modification to the original detrital quartz grains and by compaction and squeezing of relatively plastic lithic fragments between the quartz grains. Certainly the thin section now contains very little porosity and the sample undoubtedly has a very small permeability.

The fine-grained material in the rock is similar to that in the few samples described above in that it is notably heterogeneous and is therefore considered to be derived essentially completely from lithic fragments. Some of these are clearly chert but most contain at least a proportion of clay and some are monomineralic clay aggregates. Most of the fragments have a randomly oriented texture but some show the effects of squeezing between the quartz grains and others retain some evidence of an original foliation or bedding direction.

Minor detrital constituents of the rock are feldspar and muscovite. Plagioclase and potassium feldspar were both identified and the muscovite flakes show some evidence of deformation. There are traces of detrital ?biotite and a few large grains of tourmaline.

Carbonate occurs in this rock only to a very small extent and has a patchy distribution. Most commonly, the carbonate forms a fine-grained rim around small quartz grains but there are one or two larger irregular crystals also. The carbonate is an unstained variety and is probably either dolomite or siderite.

3.2 X-ray Diffraction

The results given in Table 1 list the following:

- (a) The mineralogy of the total sample, as derived from examination of the bulk material, with supporting evidence as available. The minerals found are listed in approximate order of decreasing abundance, using the semiquantitative abbreviations given. Coverage of clays may be incomplete, and for full clay mineralogy Section (c) should be consulted. This section (a) is for information on non-clay minerals and to give a general idea of the makeup and proportions.
- (b) The proportion of the sample found to separate into the $-2 \mu\text{m}$ size fraction, as determined by the plummet balance. The figure obtained applies only to the pre-treatment and dispersion conditions used.
- (c) The mineralogy of the $-2 \mu\text{m}$ fraction, presented as in Section (a).

TABLE 1: CLAY MINERALOGY

Depth (SWC)	1615.4 m(54)	2070 m(41)	2135 m(38)	2200 m(33)	2603 m(23)					
(a) Bulk Mineralogy:	Q	D	Q	D	Q	D	Q	D	Q	D
					Be	A	Cal	Tr-A	K	A
					Py	Tr	K	Tr	M	A
							F'	Tr	C	Tr-A
									F	Tr
									C	
(b) $-2 \mu\text{m}$ fract. %:	11	5	7	3	15					
(c) Mineralogy:	ML	D	Be/C*	D	Be/C*	D	Q	D	K	D
	Q	SD	M	A	Q	A-SD	K	SD	ML	SD
	K	A-SD	Q	A	M	Tr-A	M	A	M	A
	M	A	Sm	A			C	A	Q	A
							Sm	Tr-A	C	Tr
									F	Tr
Depth (SWC)	2756.9 m(18)	2794.5 m(16)	2955 m(11)	3019 m(8)						
(a) Bulk Mineralogy:	Q	D	Q	D	Q	D	Q	D		
	Cal	A	C	A	C	A	C	A		
	K	A	K	A	K	A	K	A		
	M	A	M	A	M	Tr-A	M	A		
	F	Tr-A	FF'	A	F	Tr-A	F	Tr		
(b) $-2 \mu\text{m}$ fract. %:	14	12	11	8						
(c) Mineralogy:	ML	D	ML	D	C	D	C	D		
	K	SD	C	SD	K	SD	ML	A-SD		
	M	A	K	SD	ML	SD	K	A-SD		
	Q	A	M	A	Q	A	M	A		
	C	A	Q	A	M	Tr	Q	A		
	Cal	Tr	F	Tr	F	Tr	F	Tr		
	F	Tr								

*Note on berthierine and chlorite: XRD peak overlaps prevent proper assessment of amounts of these two minerals separately; thus they are reported together. In both cases it appears that berthierine predominates over chlorite, probably considerably.

Semiquantitative Abbreviations:

- D = Dominant. Used for the component apparently most abundant, regardless of its probable percentage level.
- CD = Co-dominant. Used for two (or more) predominating components, both or all of which are judged to be present in roughly equal amounts.
- SD = Sub-dominant. The next most abundant component(s) providing its percentage level is judged above about 20.
- A = Accessory. Components judged to be present between the levels of roughly 5 and 20%.
- Tr = Trace. Components judged to be below about 5%.

Mineral Key

Be	Berthierine (formerly 7Å chamosite) - ferric form
C	Chlorite
Cal	Calcite
F	Feldspar (plag., albite)
F'	K feldspar
FF'	Both feldspars present, first more abundant
K	Kaolinite
M	Mica/Illite
ML	Randomly-interstratified mixed-layer smectite-illite (approximately equal proportions of 2 layer type)
Py	Pyrite
Q	Quartz
Sm	Smectite

3.3 Scanning Electron Microscopy

SEM examinations are illustrated by a series of plates in Appendix 2. The captions on these plates highlight the relevant features of each sample.

4. DISCUSSION

The sandstones examined from 2603 metres depth and below are distinctly different from the overlying sandstones examined (1615.5-2200 metres depth). The major difference between these two groups of sandstones stems from differing proportions of lithic fragments. Lithic fragments typically comprise 30-50% of the sample volume in the sandstones below 2603 metres depth. Lithic fragments are either absent or present in only trace amounts in the sandstones from the 1615.5-2200 metres depth interval. These lithic fragments contain variable amounts of randomly-interstratified mixed-layer smectite-illite, chlorite, kaolinite, mica and quartz. Of these minerals, the most reactive (in terms of swelling) is the mixed layer clay.

A comparison of the XRD data with the maximum caliper measurements of the sands associated with these sediments reveals that the sandstones containing mixed-layer clays (1615.5' and 2603-3019 metres depth) are much more likely to "washout" than the sandstones which do not contain mixed-layer clays (2070-2200 metres depth interval). It seems likely that these clays swell during drilling causing the sandstones to disintegrate. The severity of the problem appears to be dependent on the abundance of lithic fragments and the abundance of mixed-layer clay in these fragments. The presence of carbonate and quartz overgrowths may minimise the washout effect to some degree by cementing the quartz and larger mineral grains together.

APPENDIX 1

THIN SECTION PLATES

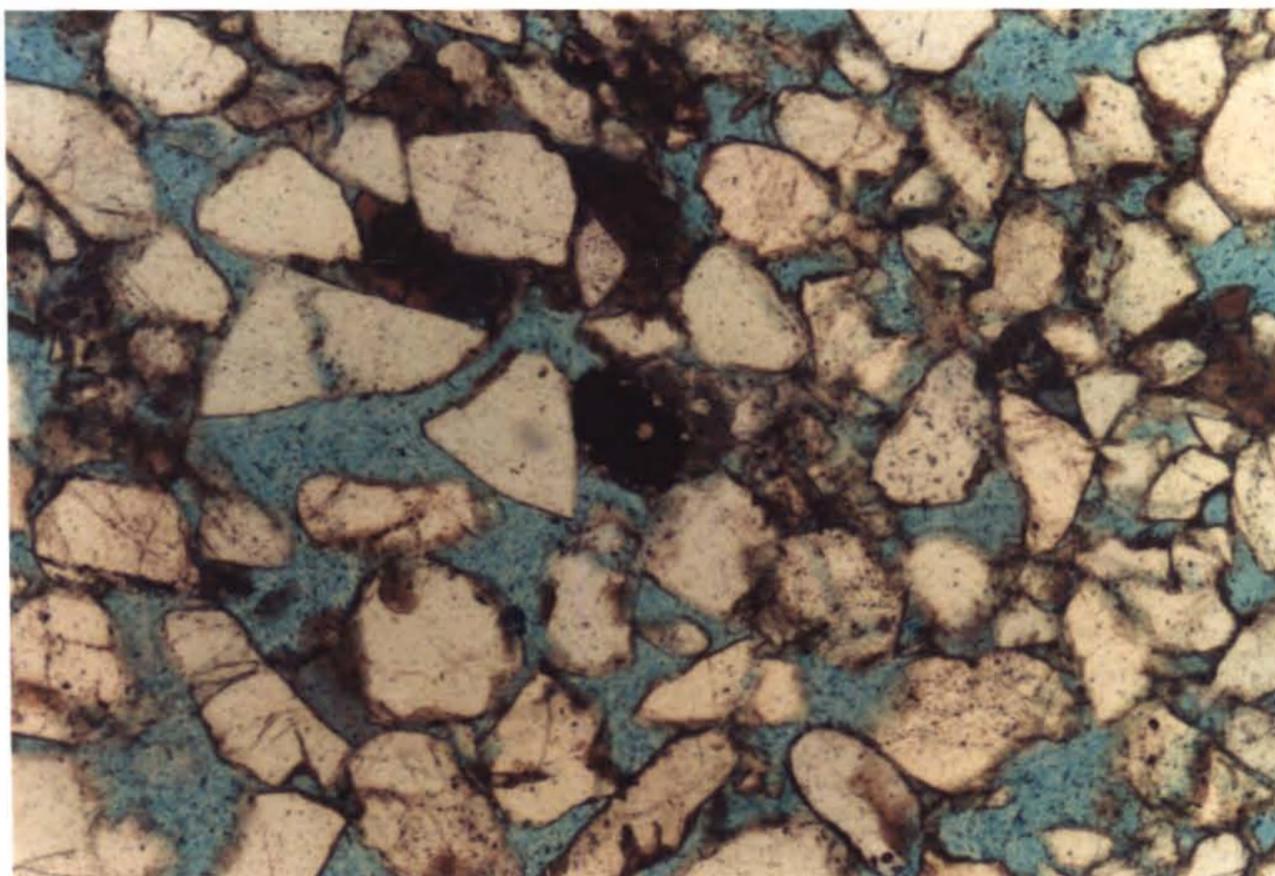


PLATE 1a: 2070 m (ppL). Blue is pore space. Note patchy brown clay. The almost opaque patch near the centre is carbonate.

5 cm

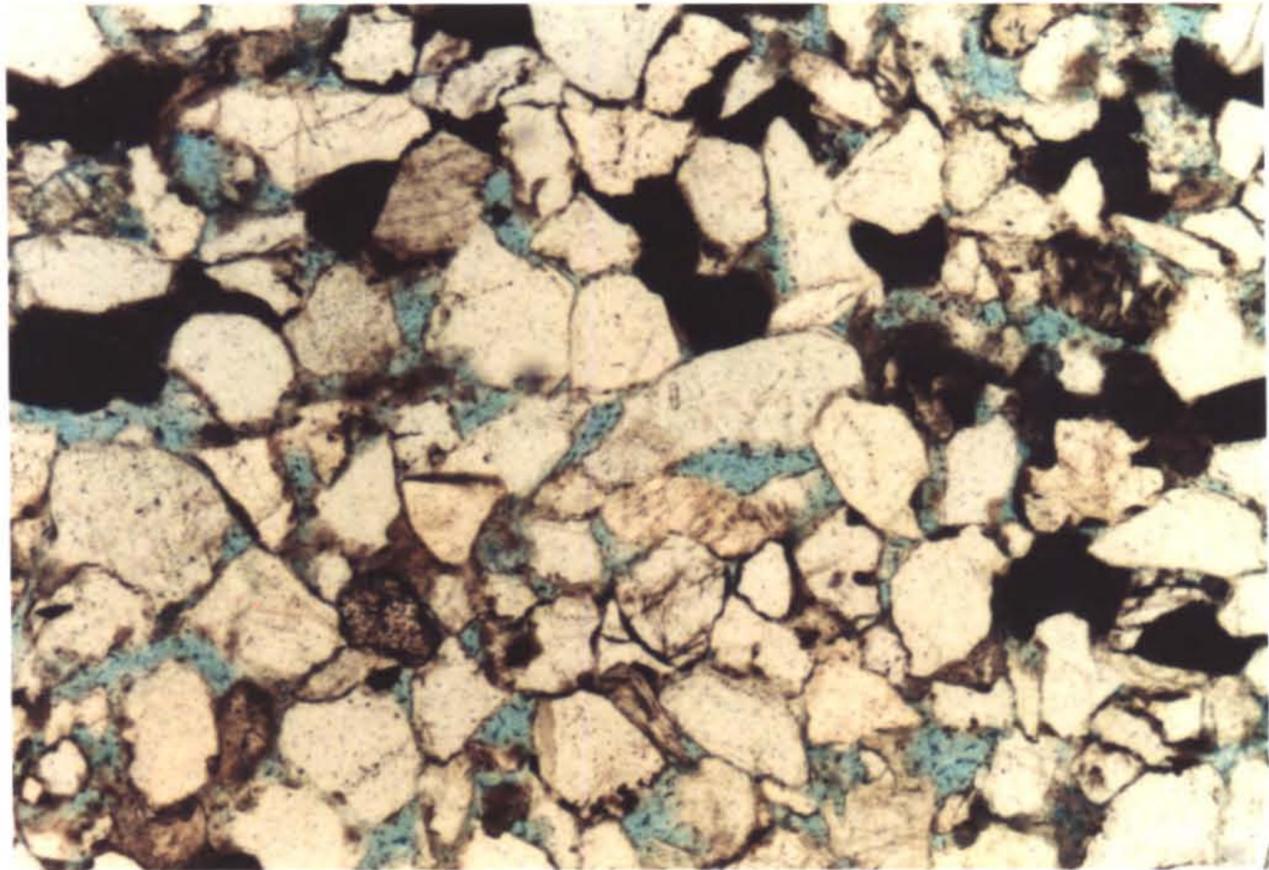


PLATE 1b: 2135 m (ppL). Rather compacted area with some curved grain contacts.

5 cm

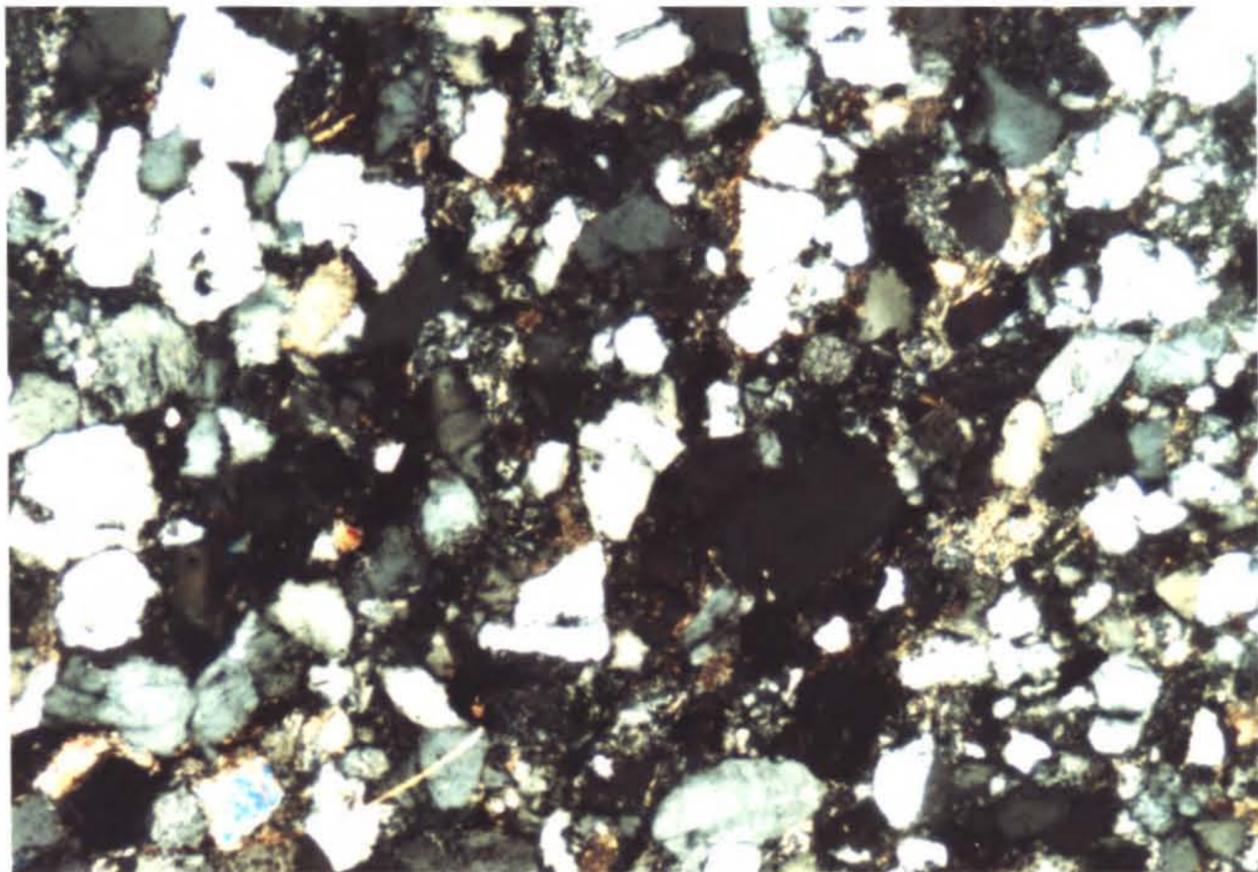
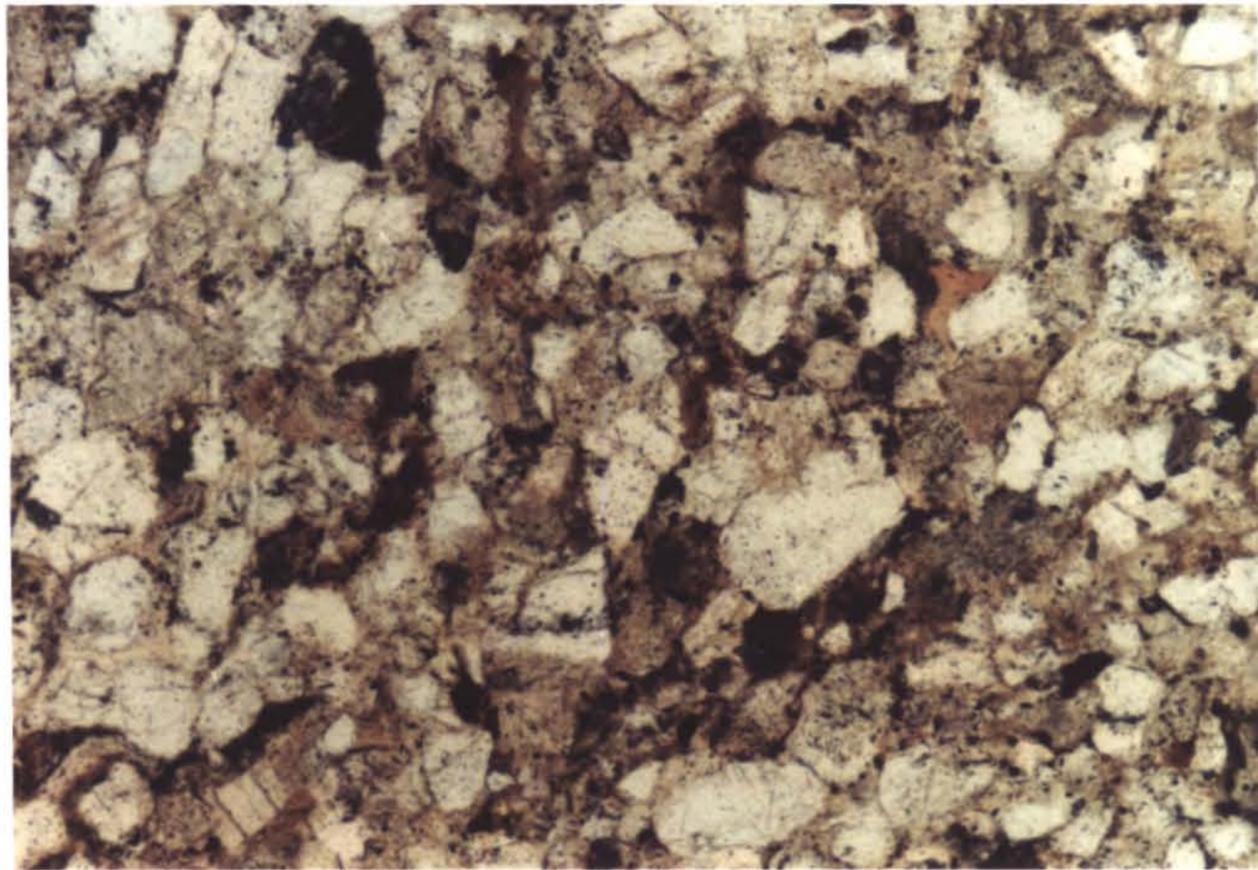


PLATE 2: 2602 m (ppL and crossed Nicols). The sandstone contains abundant heterogeneous clay. Contrast with plates 1a and 1b.

5 cm

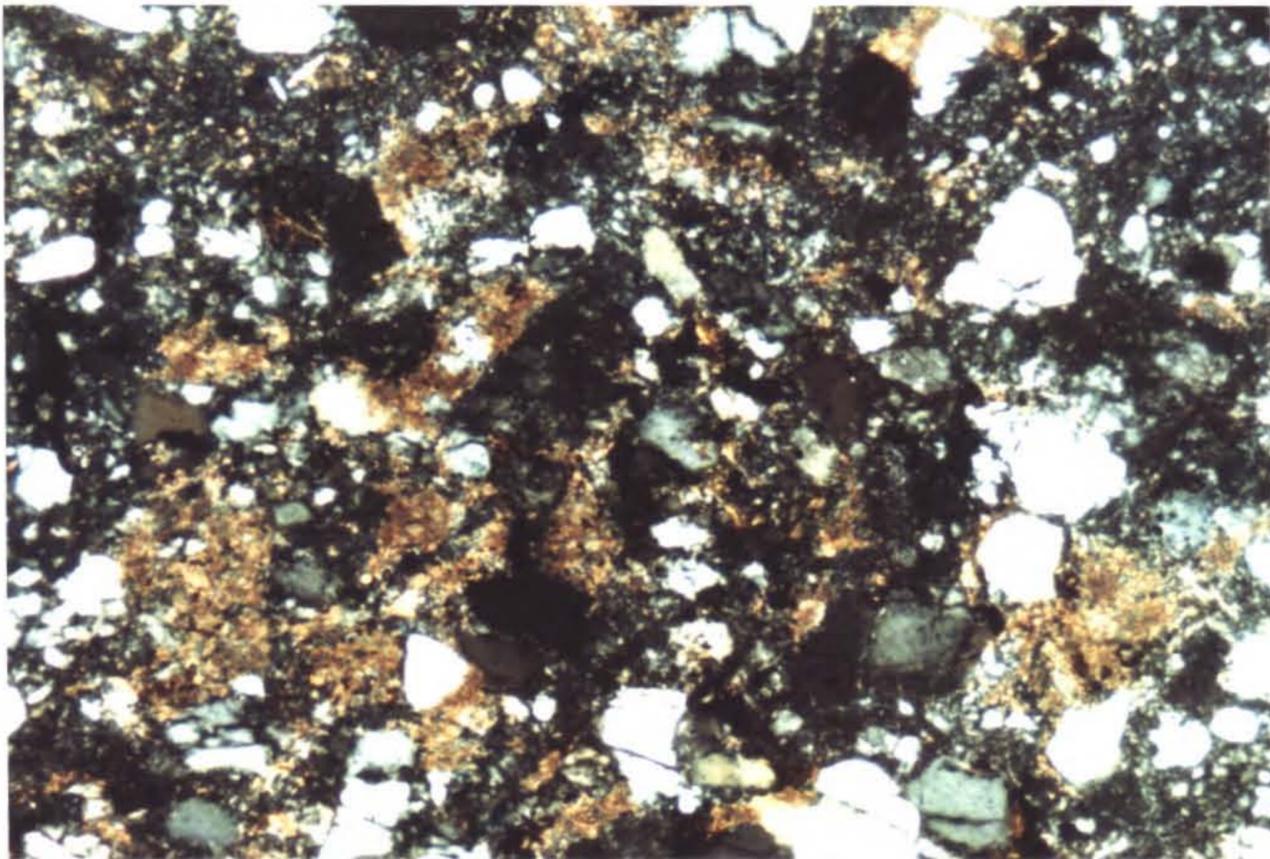
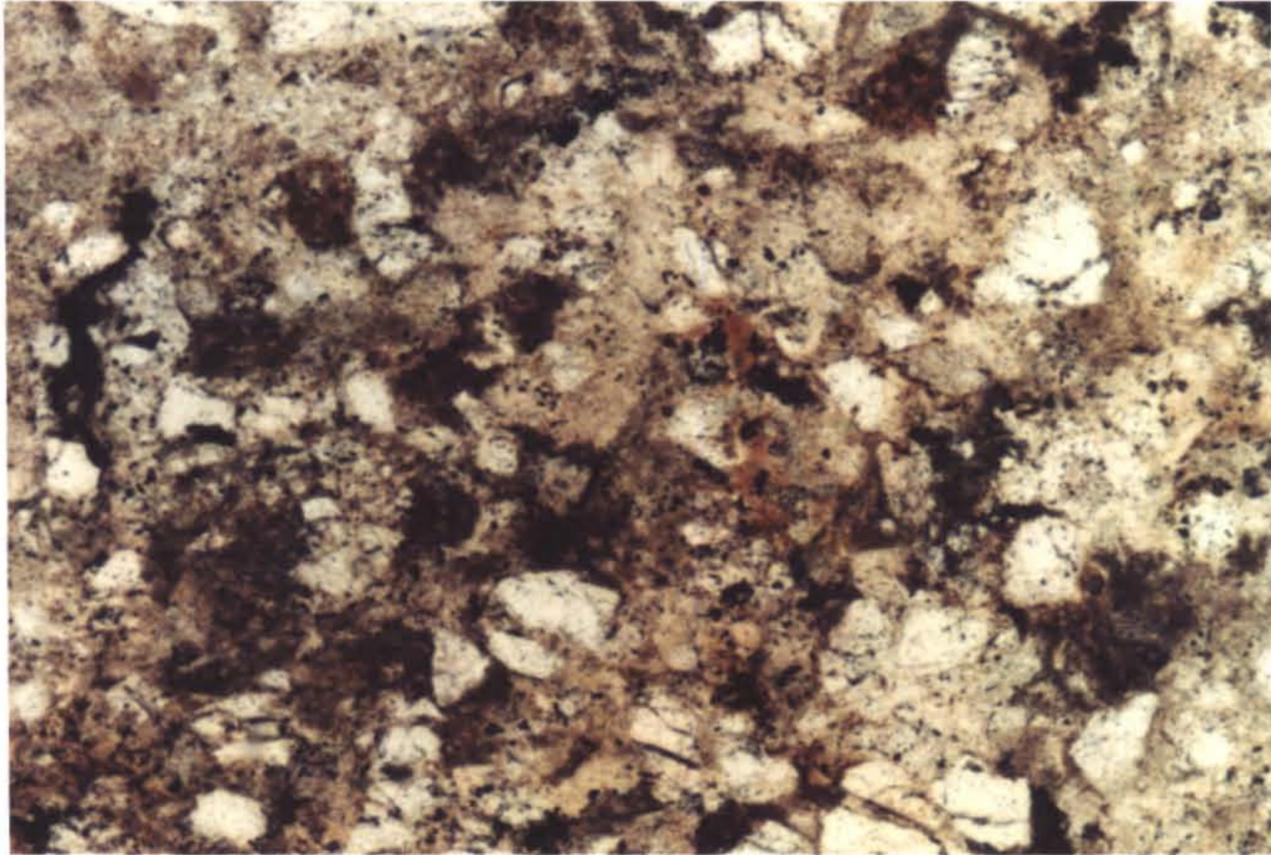
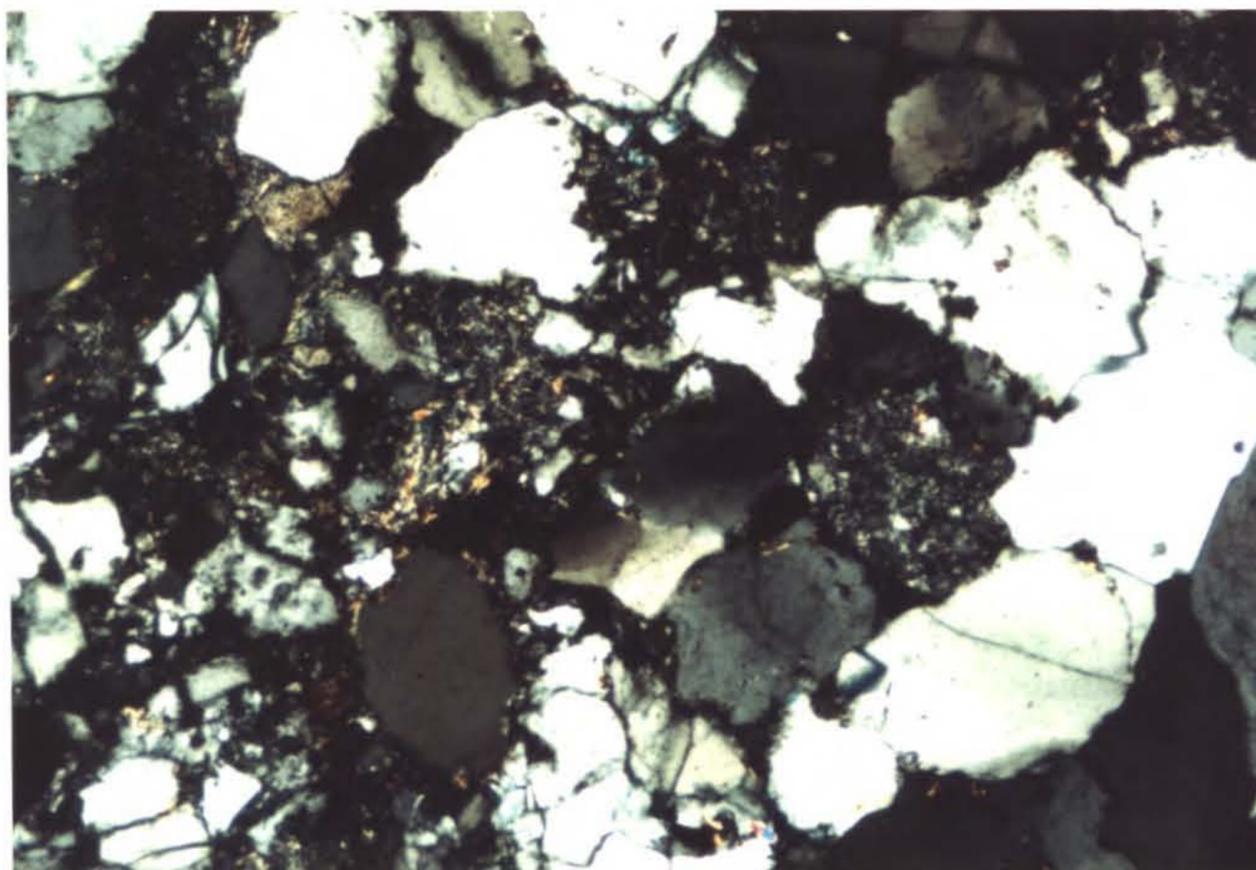
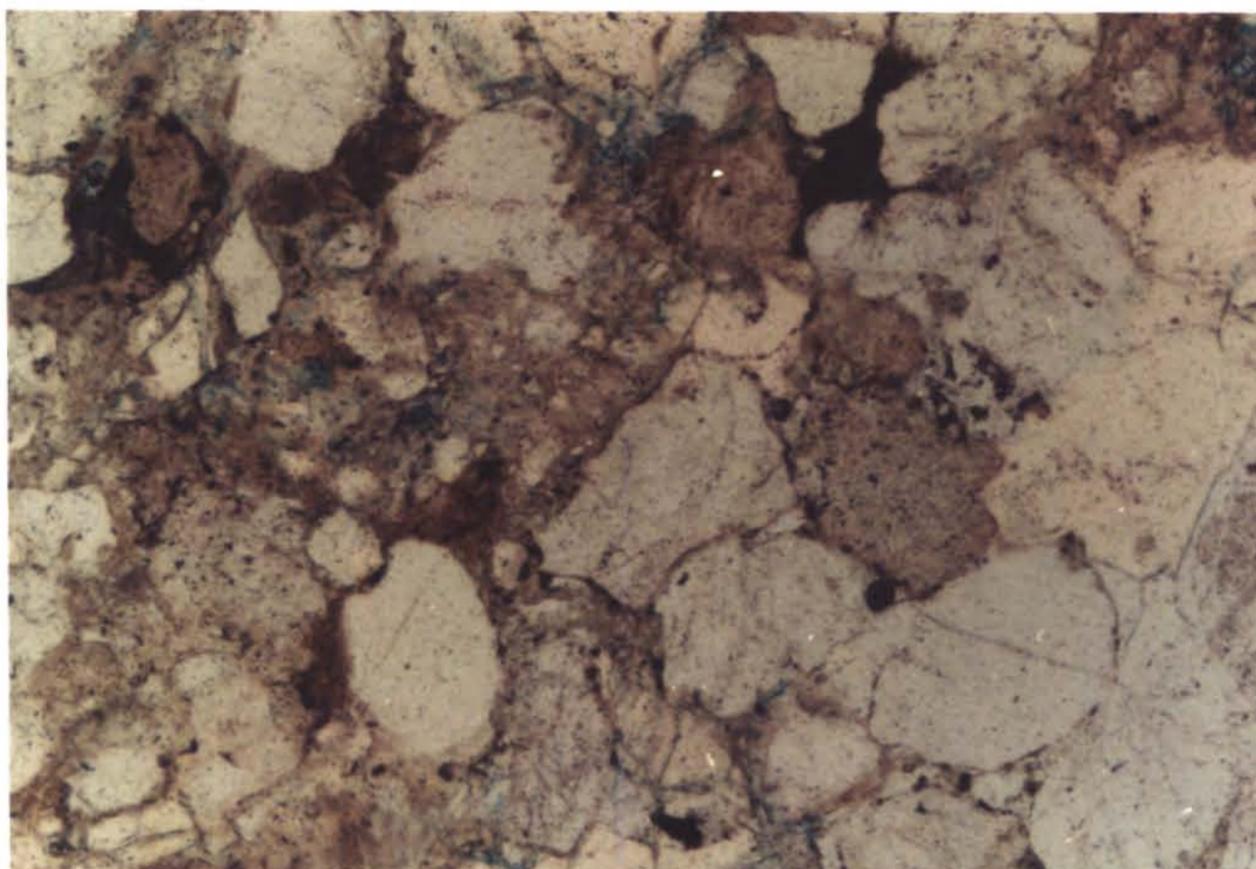


PLATE 3: 2757 m (ppL and crossed Nicols). Similar to plate 2 but note, in lower photograph, the brown fine-grained carbonate.

5 cm



5 cm

PLATE 4: 3019 m (ppL and crossed Nicols). Coarser-grained than plates 2 and 3. Also shows some quartz overgrowths. Porosity (blue, upper photo) is associated with porous clay mosaics.

APPENDIX 2

SEM PLATES

PLATE 1: 1615.5 m; SWC 54
This plate shows authigenic kaolinite (right) adjacent to
a lithic fragment consisting largely of mixed-layer clays
and illite.

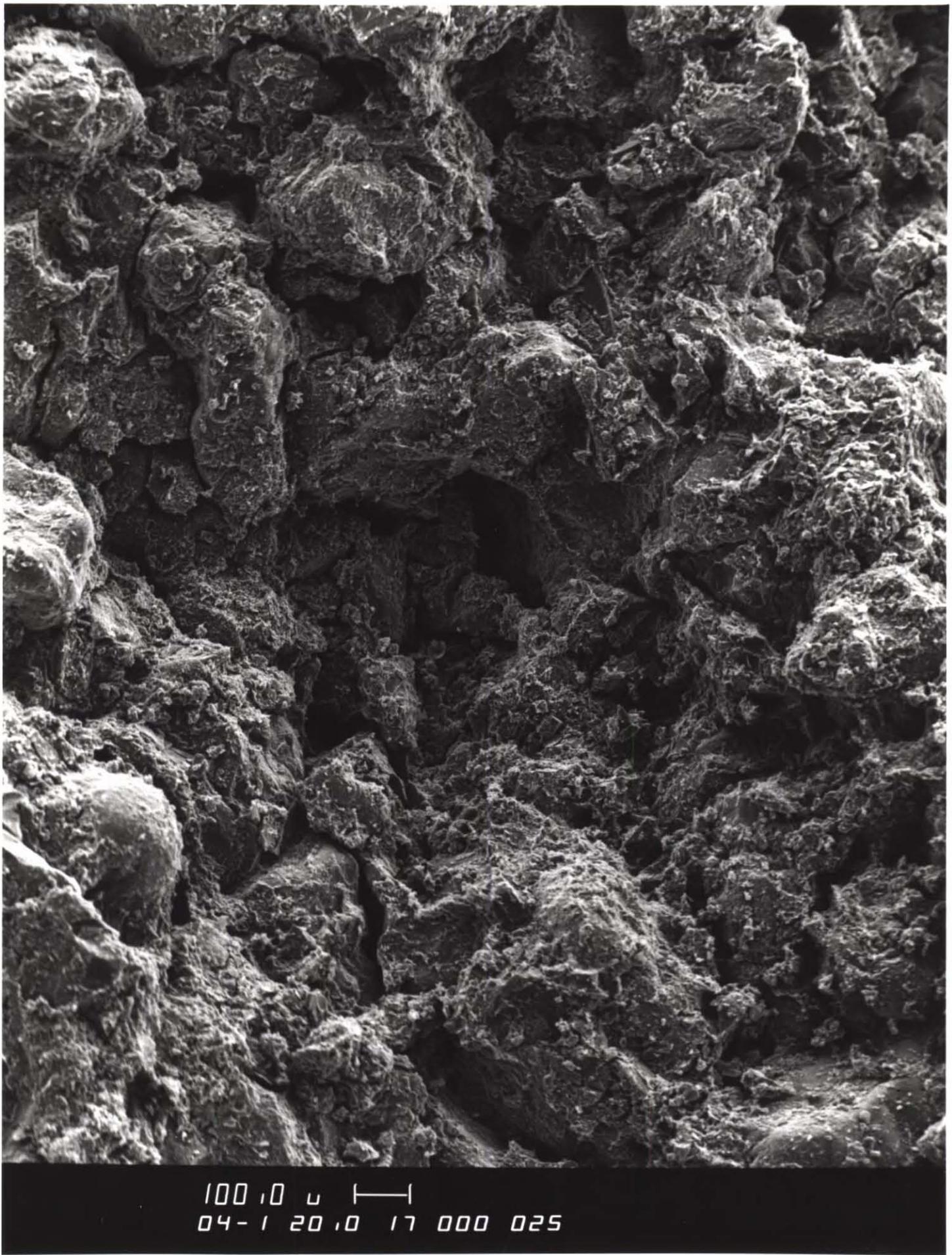


0 10 .0 μ |-----|
11-2 20 .0 17 000 027

5 cm

282025

PLATE 2: 1615.5 m; SWC 54
This sandstone is moderately well-sorted and consists of well rounded quartz grains with a clay matrix.

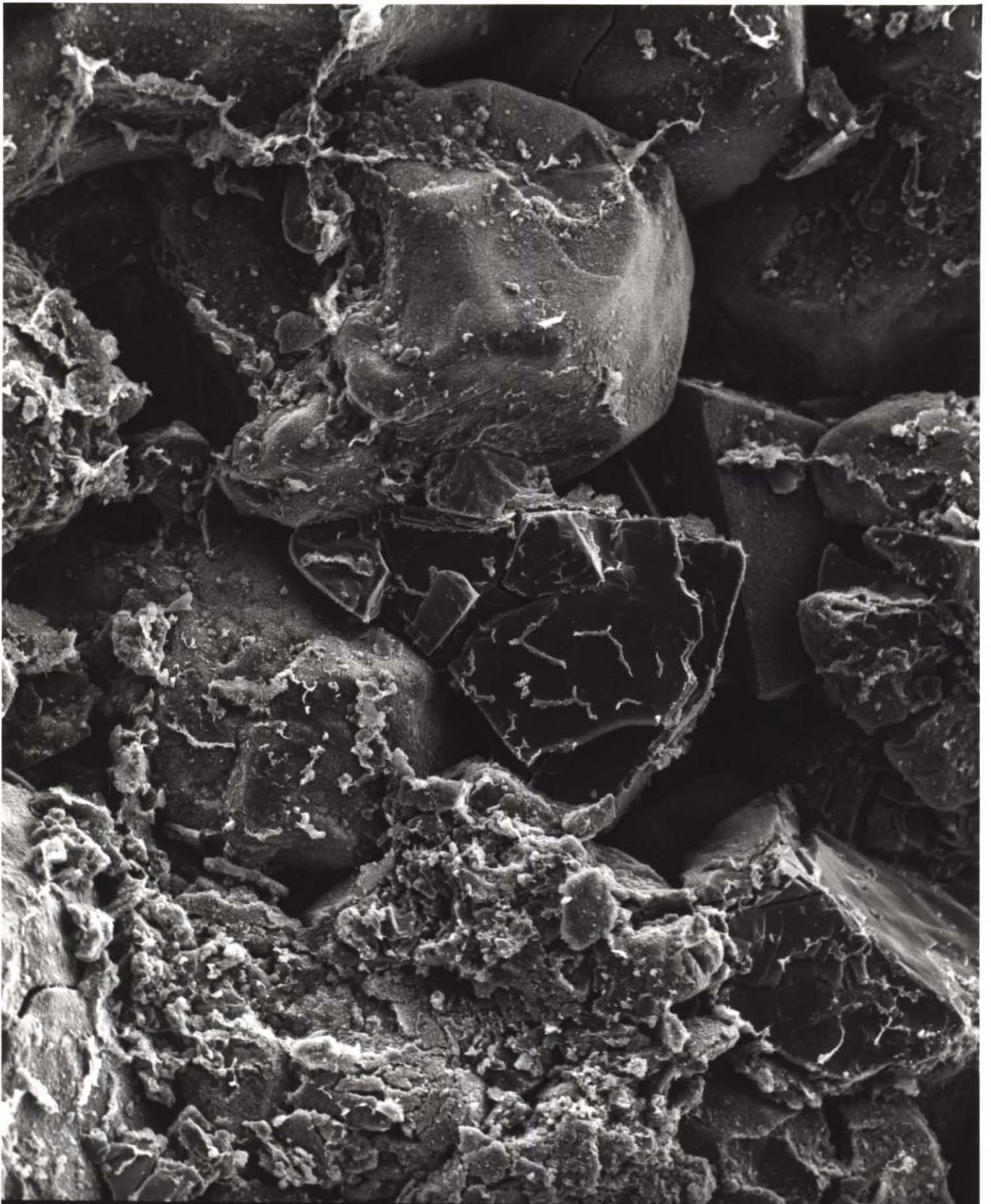


100.0 \times |—|
04-1 20.0 17 000 025

5 cm

282027

PLATE 3: 2070 m; SWC 41
The quartz grains are coated with berthierine which may have inhibited pressure solution effects at the grain contacts.



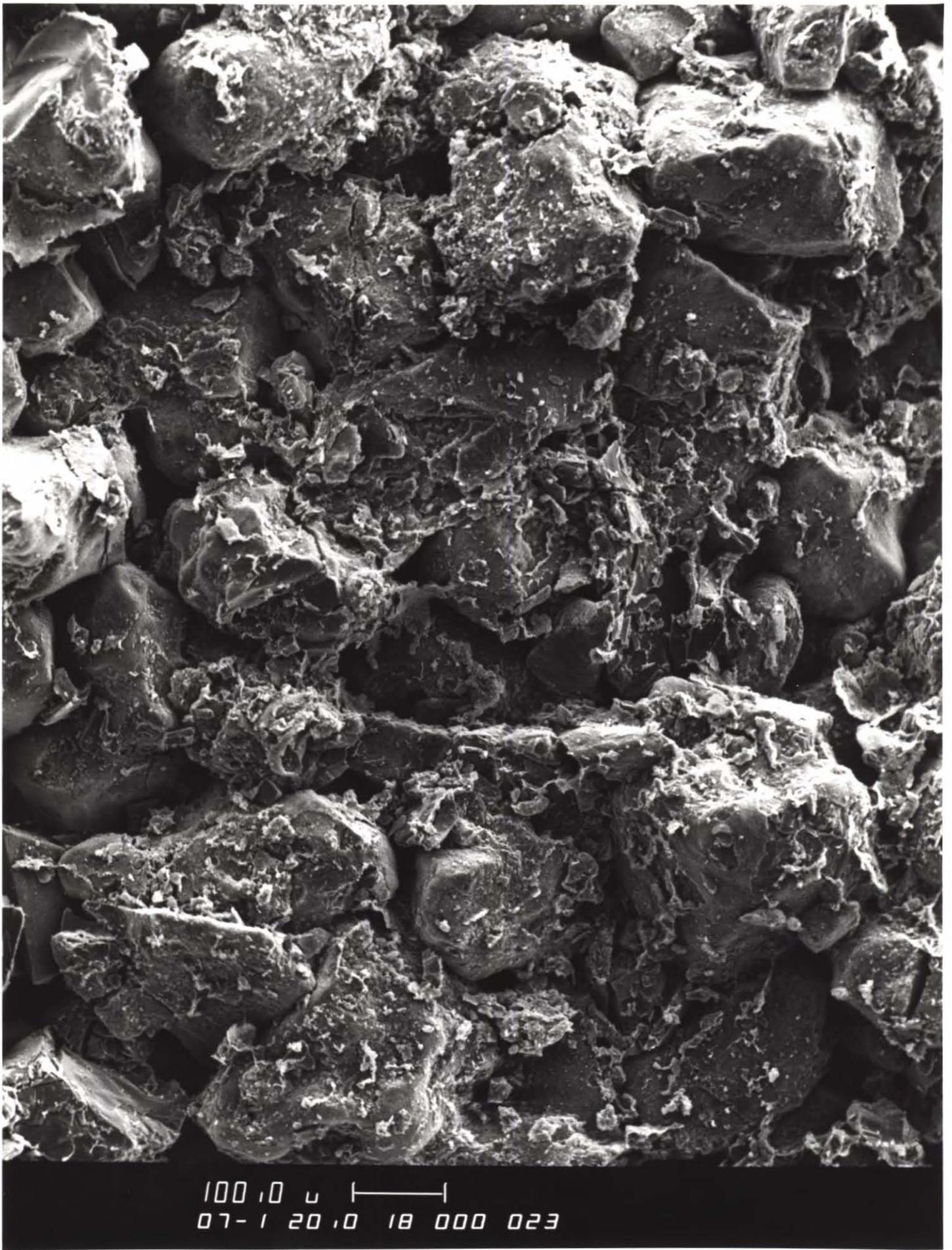
010,0 u H
01-2 20,0 18 000 024

5 cm

282029

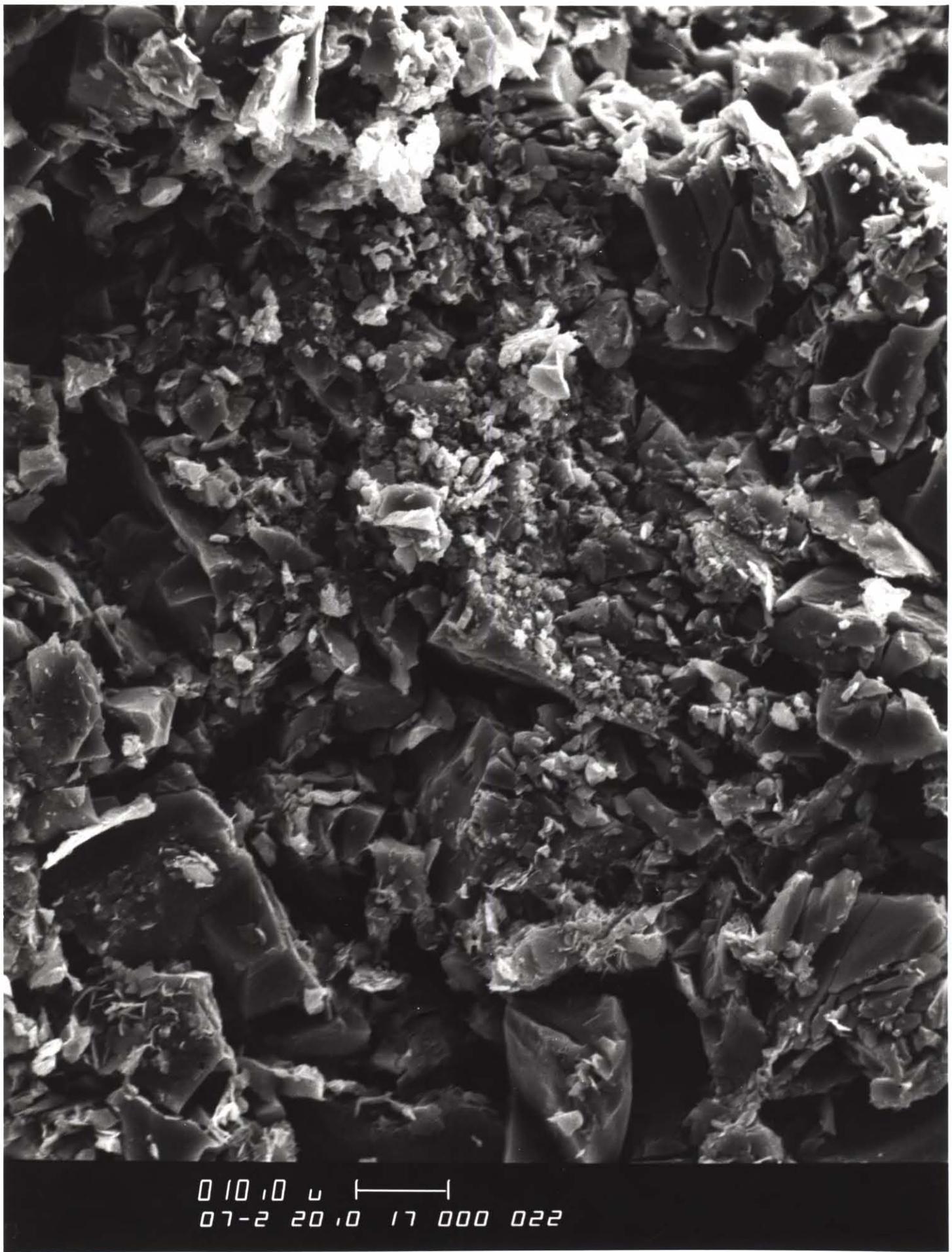
PLATE 4: 2070 m; SWC 41

This plate shows that this sandstone is clearly highly porous and poorly cemented. Quartz grains are generally well-sorted and fairly well rounded.



5 cm

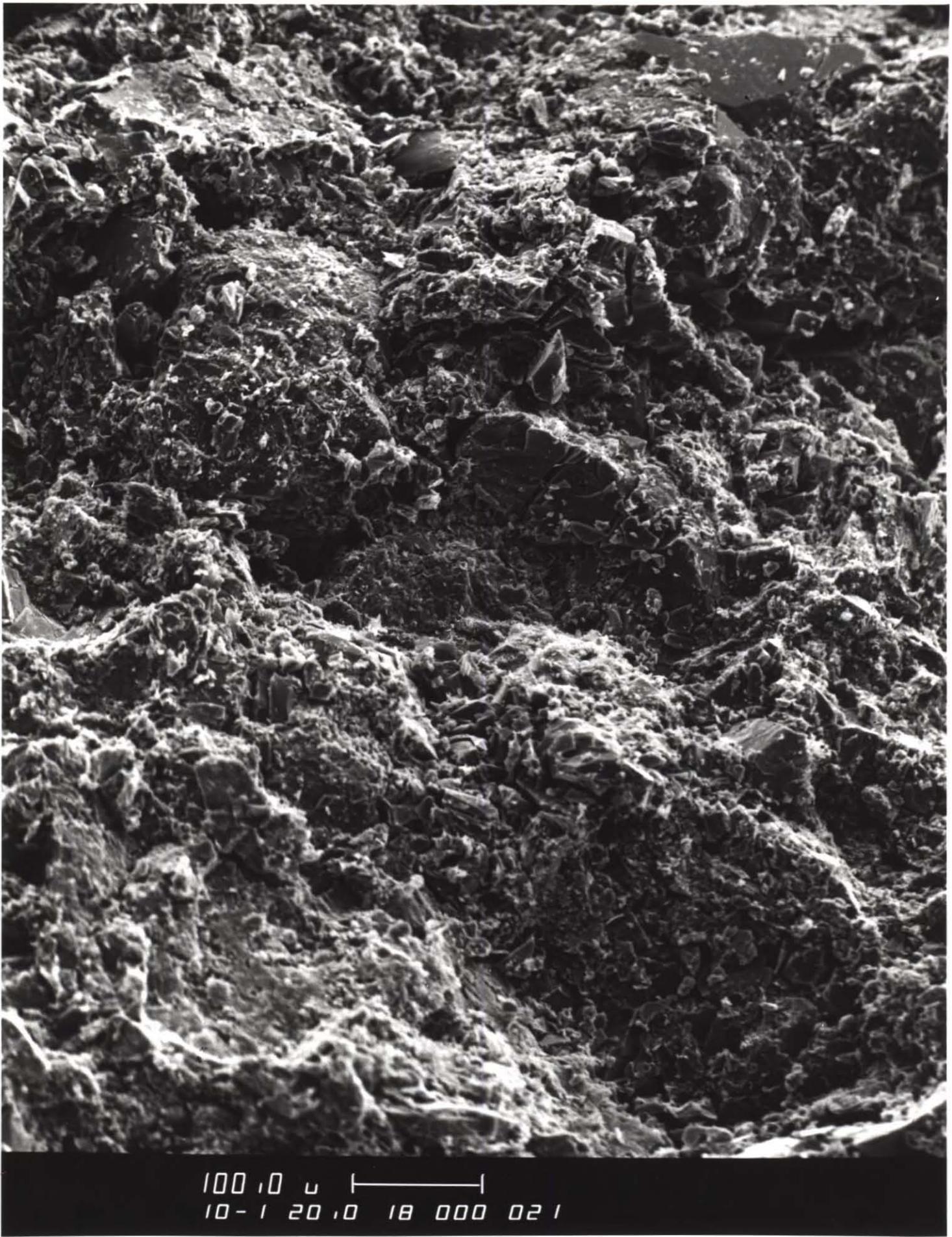
PLATE 5: 2135 m; SWC 38
The matrix consists largely of quartz with minor clay
(berthierine (formerly chamosite; upper field) and chlorite
(authigenic, lower field)).



5 cm

282033

PLATE 6: 2135 m; SWC 38
This is a poorly sorted sandstone consisting largely of subrounded quartz grains and a fine-grained, quartz-rich matrix.



100 10 u
10-1 20 10 18 000 02 1

5 cm

282035

282036

PLATE 7: 2200 m; SWC 33

The friable nature of this sandstone is illustrated by the deep cavity remaining after a quartz grain was plucked from this sample during preparation. The fine-grained material is quartz.



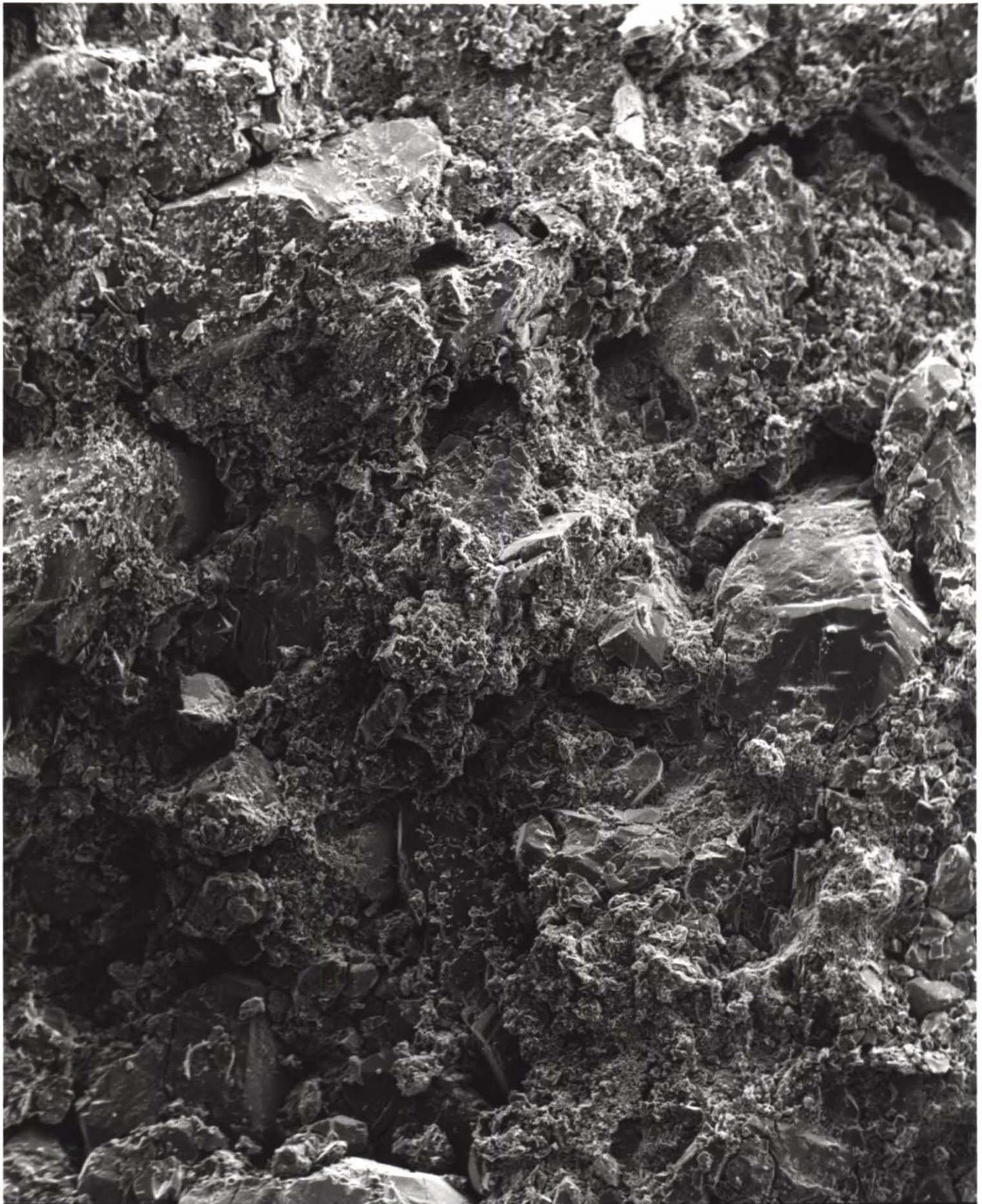
0 10 10 u H
0 1-2 20 10 17 000 020

5 cm

282037

PLATE 8: 2200 m; SWC 33

This sandstone consists of fine-grained quartz grains in a matrix of silt-sized quartz and minor carbonate. The sample contains very little clay.

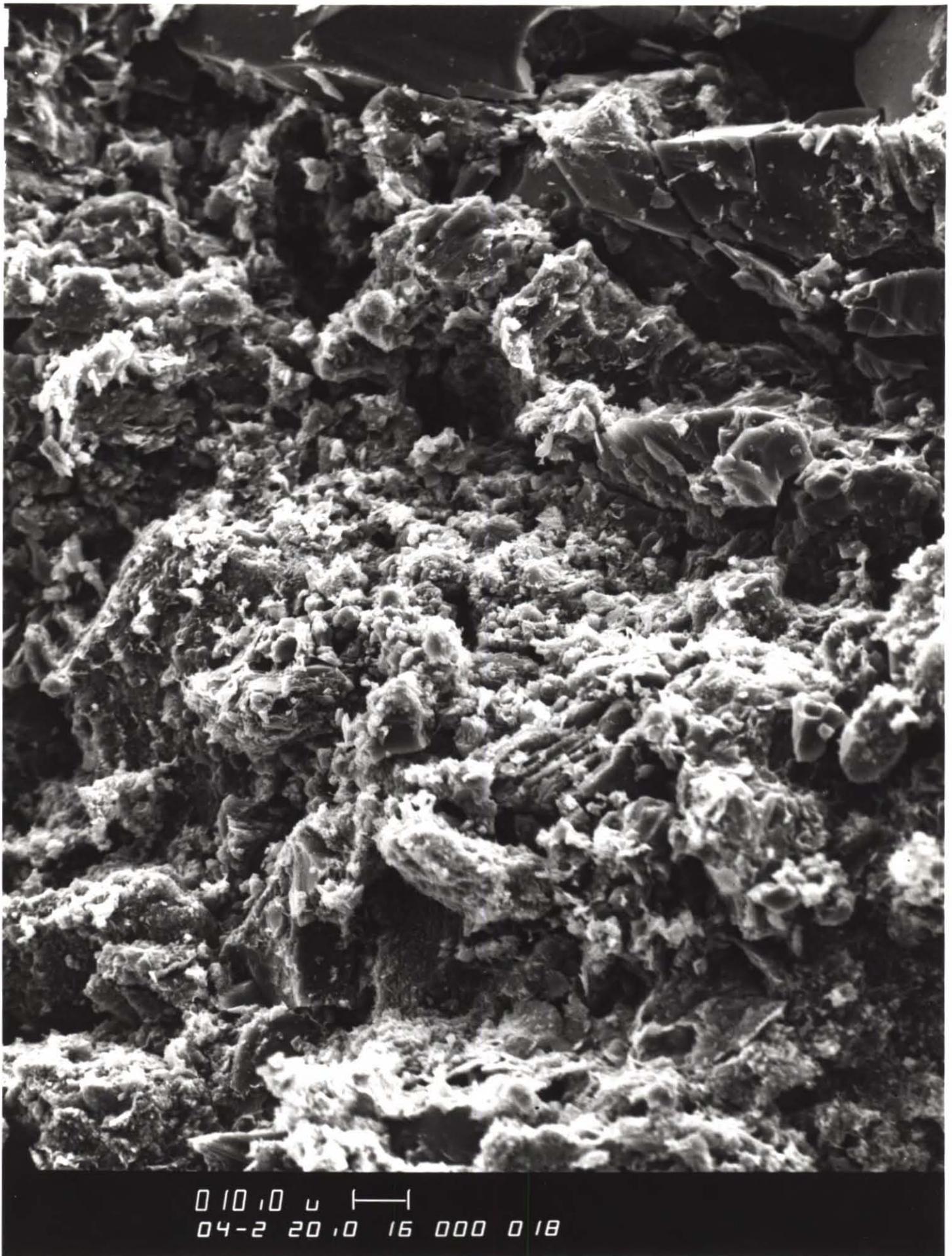


100.0 u |
04-1 20.0 17 000 019

5 cm

282039

PLATE 9: 2603 m; SWC 23
This plate shows carbonate (top right), between a lithic fragment (consisting of fine-grained quartz and clay) and an angular quartz grain.



0 10 .0 u |
04-2 20 .0 16 000 0 18

5 cm

282041

PLATE 10: 2603 m; SWC 23

This sample contains abundant lithic clasts which constitute approximately 50% of the sample volume. Some porosity occurs adjacent to quartz grains where these lithic fragments are rare (slightly above centre field).



100.0 u |
05-1 20.0 16 000 0 15

5 cm

282043

PLATE 11: 2756.9 m; SWC 18
Clay minerals in this sandstone generally occur in the lithic fragments, however, this plate shows some authigenic kaolinite (upper field) and illite (lower field) coating quartz grains.

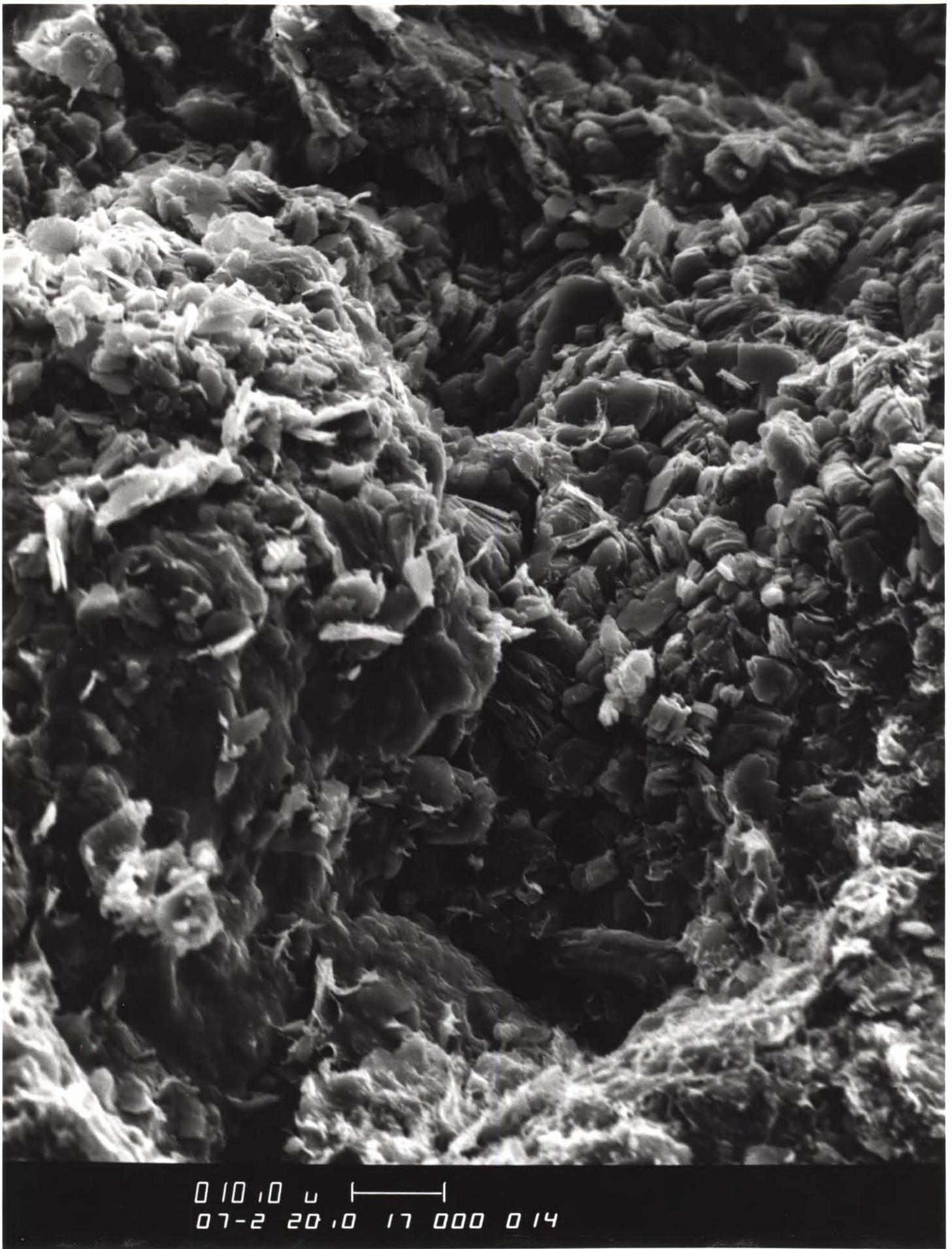
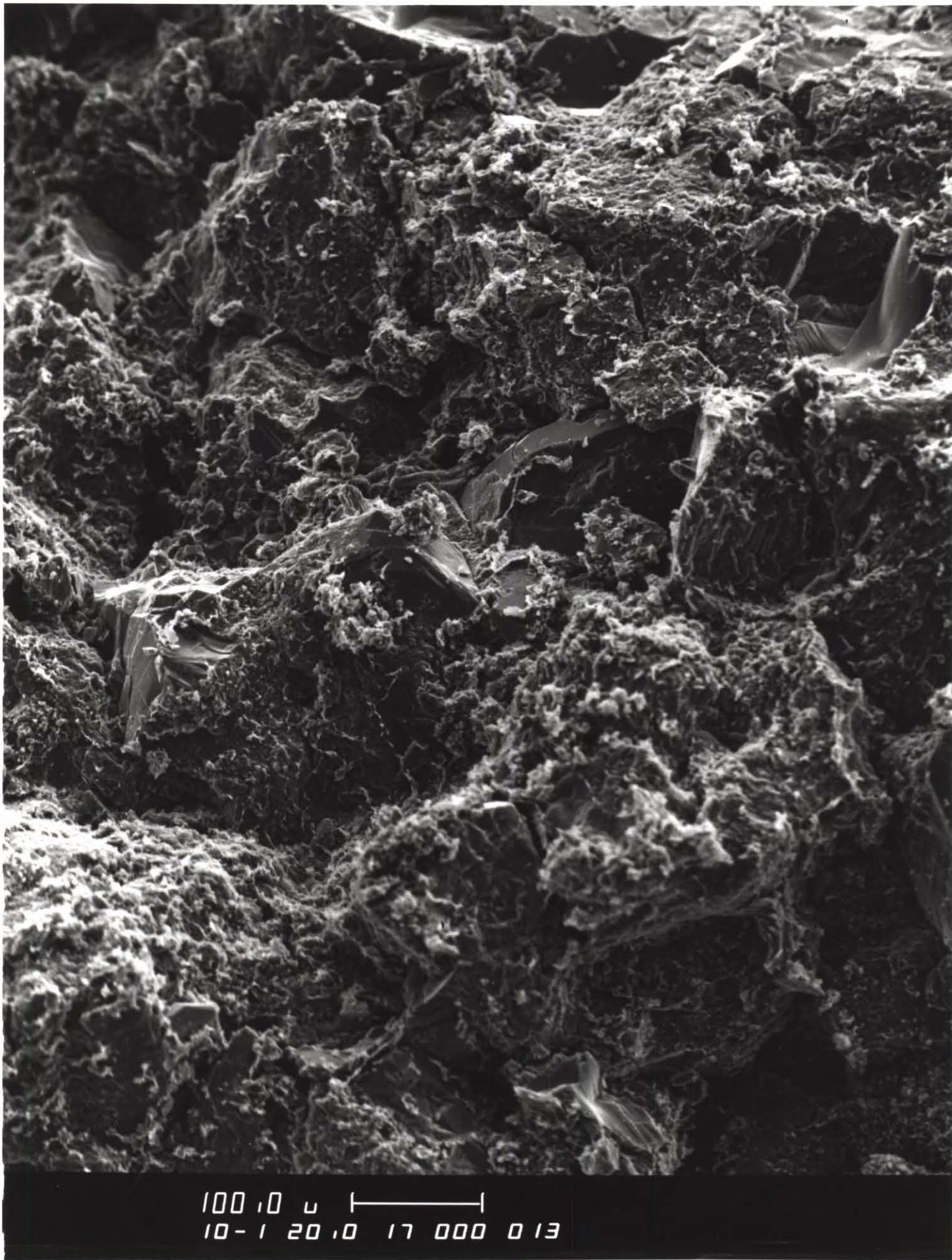


PLATE 12: 2756.9 m; SWC 18

This fine-grained sandstone is fairly well cemented by carbonate. However the distribution of carbonate is patchy resulting in well-cemented nodules.



100.0 μ |-----|
10-1 20.0 17 000 0 13

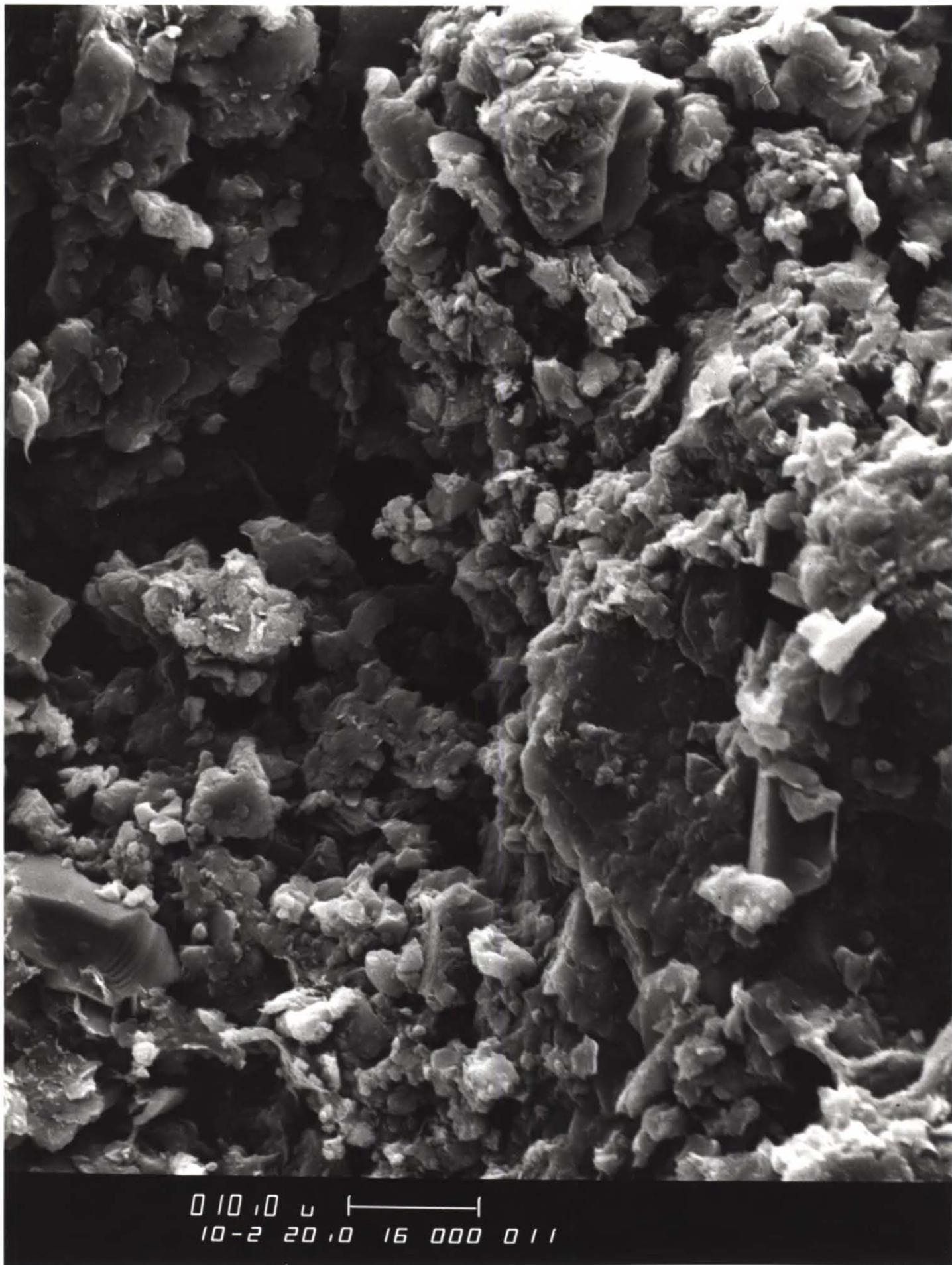
5 cm

282047

282048

PLATE 13: 2794.5 m; SWC 16

This plate shows clay minerals (probably of lithic origin - mainly mixed-layer, chlorite and kaolinite) interstitial to the quartz grains in the sandy portion of this sample.

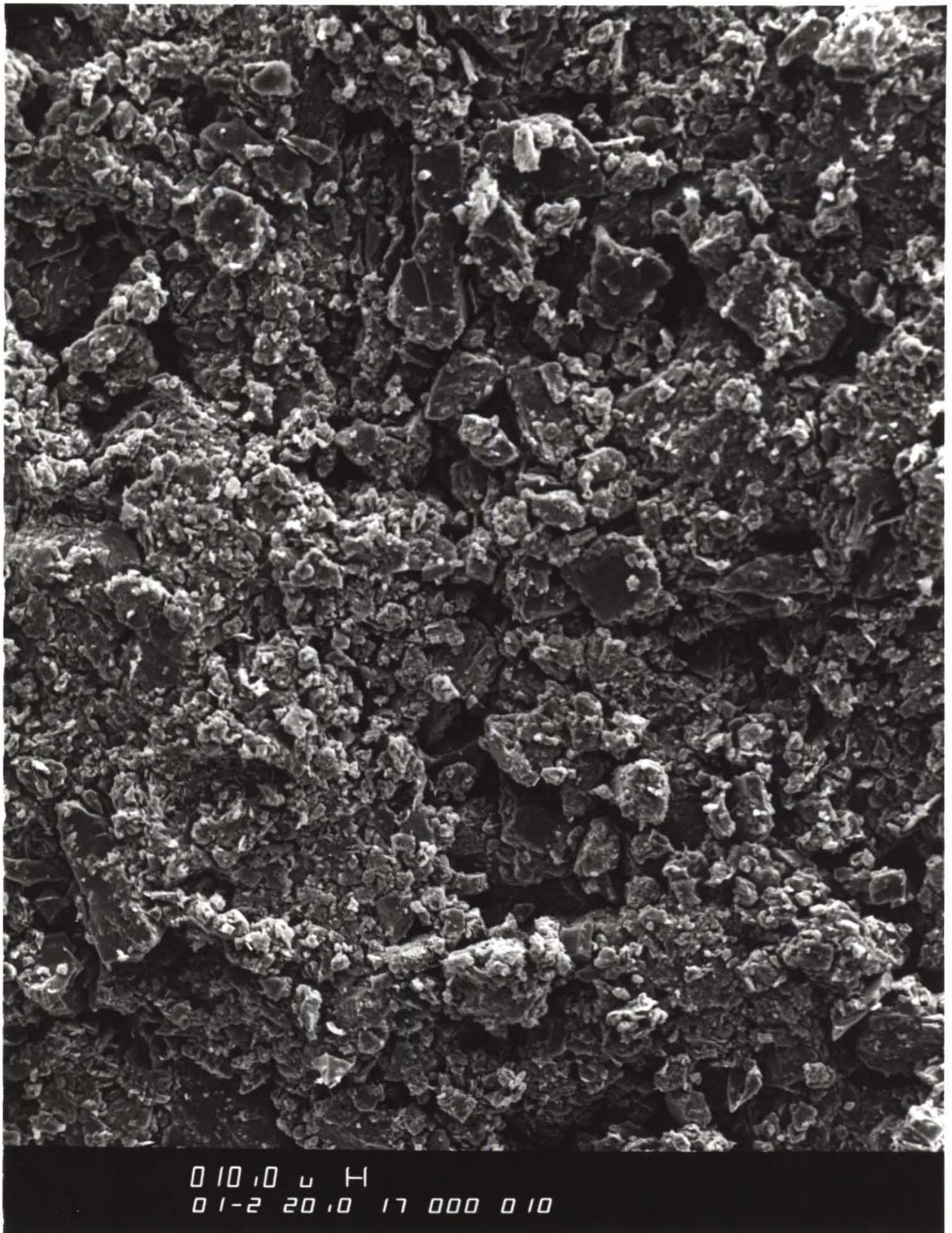


5 cm

282049

PLATE 14: 2794.5 m; SWC 16

This sidewall core is a mixture of fine-grained shaly sediment and fine-grained sandstone. This sandstone portion appears to be quite porous and the individual quartz grains are angular.



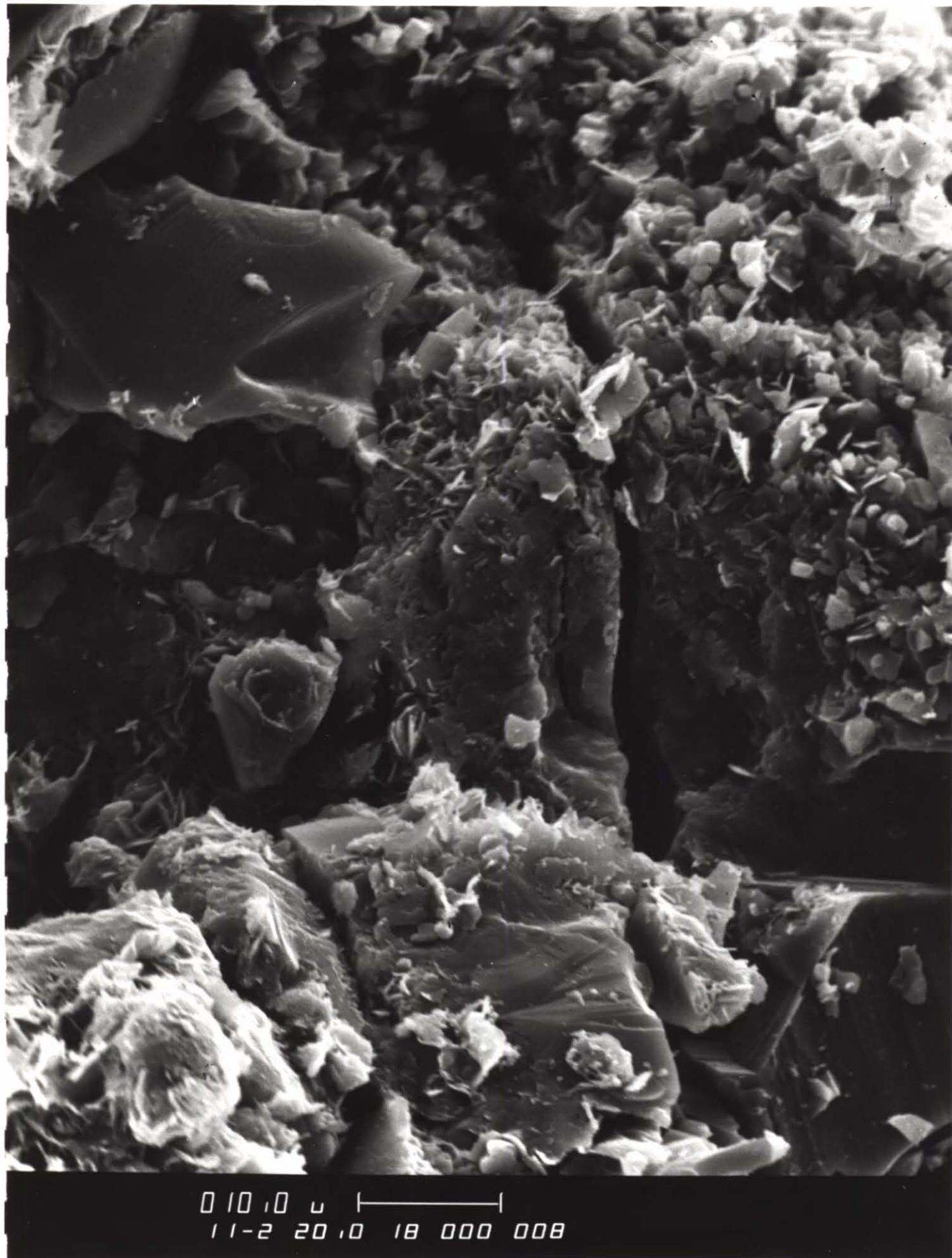
0 10.0 u H
0 1-2 20.0 17 000 0 10

5 cm

282051

PLATE 15: 2955 m; SWC 11

This plate shows authigenic clay minerals (chlorite and minor kaolinite) coating overgrown quartz grains.

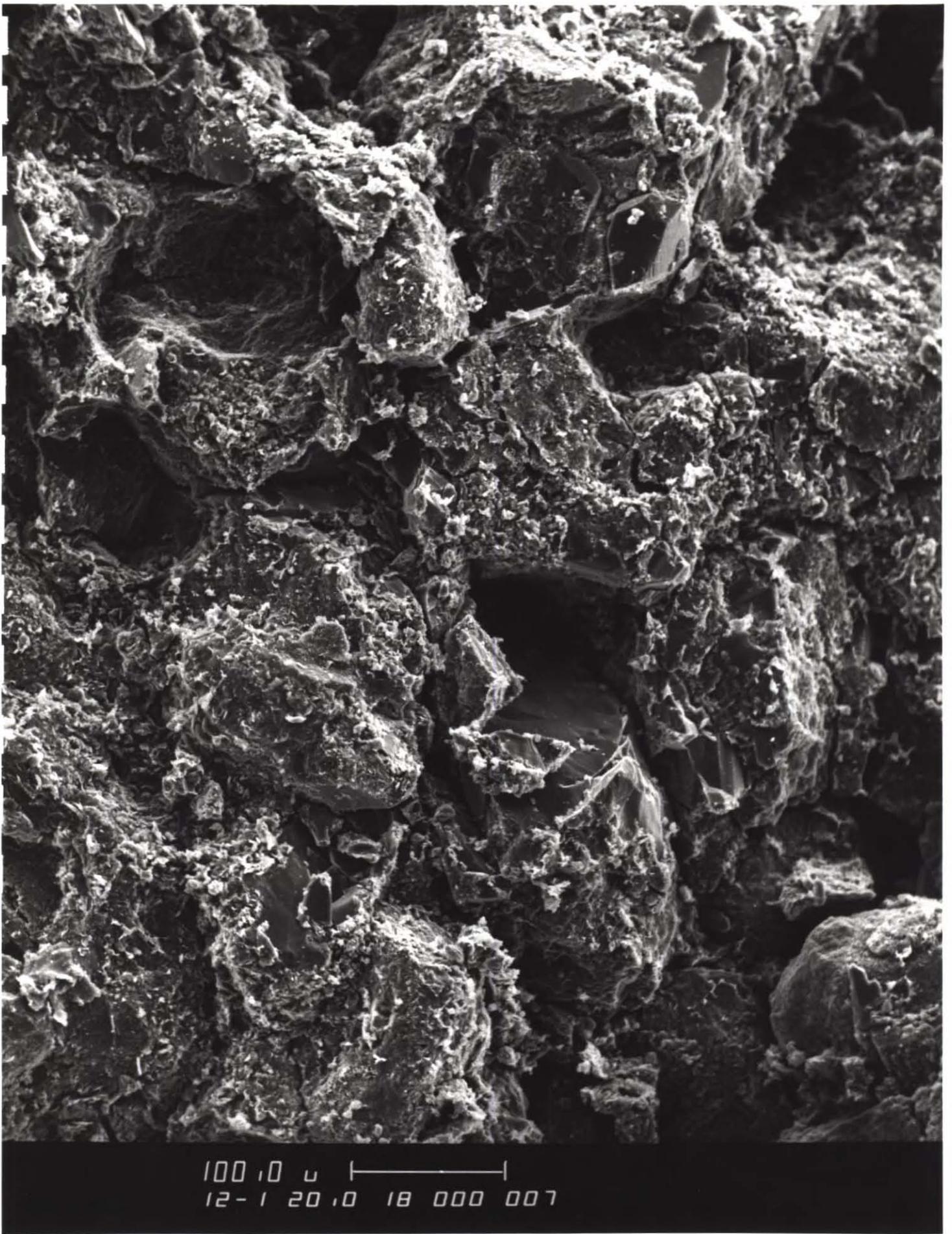


10 000 X |-----|
20.0 11-2 18 000 008

5 cm

282053

PLATE 16: 2955 m; SWC 11
Lithic fragments are clearly less abundant than in the previous sample. Porosity occurs largely between the overgrown quartz grains.



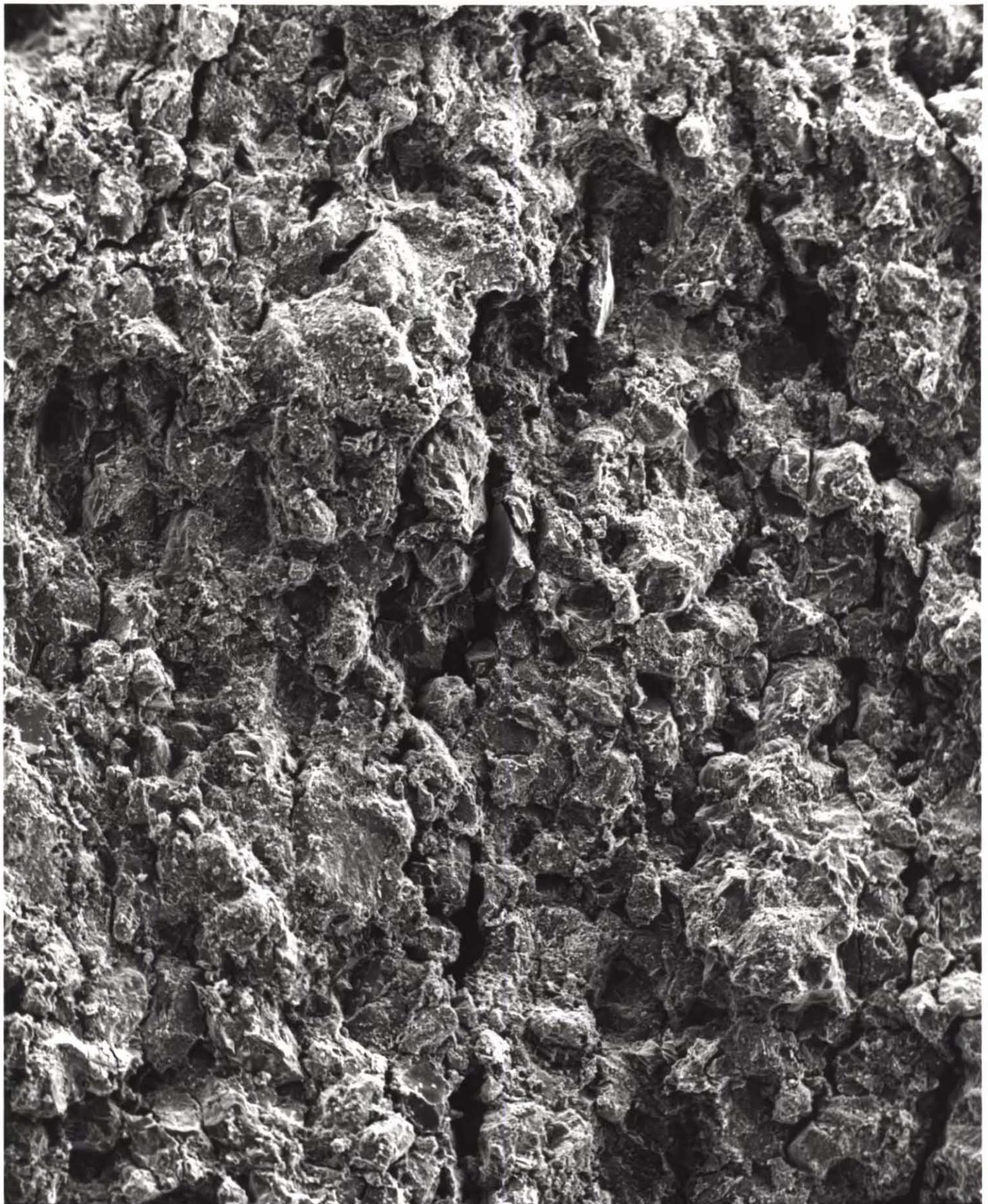
100.0 μ |—————|
12-1 20.0 18 000 007

5 cm

282055

PLATE 17: 2955 m; SWC 11

The quartz grains in this sandstone are angular as a result of quartz overgrowths. The north-south fractures are probably a result sample collection but illustrate planes of weakness in this sandstone.



100.0 μ H
02-1 20.10 23 000 006

5 cm

282057

PLATE 18: 3019 m; SWC 8

The upper portion of this field shows a lithic fragment consisting largely of small quartz fragments and clays (mixed-layer). A band of authigenic kaolinite (lower field) fills a pore space between the lithic fragment and a quartz grain.



010,0 u |
03-2 20,0 18 000 003

5 cm

282059

PLATE 19: 3018 m; SWC 8

This plate shows angular quartz grains in a matrix of lithic fragments. Most of the porosity occurs at the interstices of the quartz grains.



100.0 μ |——|
06-1 20.0 19 000 001

5 cm

282061