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A PETROGRAPHIC STUDY OF TWELVE DRILL CUTTING SAMPLES FROM THE MISSISSIPPIAN AT THE AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45 LOCATION

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EXECUTIVE SUMMARY

Thin section and SEM petrography was conducted on twelve samples of drill cuttings from the Mississippian at the Amoco S. Pointed Mountain (D-1) L-68-60-20-123-45 location. Seven samples (samples 2 to 19) are characterized by micro- to medium / very coarse crystalline siliceous limestone, which are further subdivided into three types: 1) wackestone/mudstone to grainstone (samples 2, 5 and 19), 2) mudstone to packstone (sample 8, 11 and 17) and 3) mudstone to wackstone (sample 14). The subdivision of this limestone depends on the amount of micrite matrix material. Bioclasts are the main framework grain in this limestone. Echinoid, siliceous sponge spicules and pelecypod or brachiopod shell fragments are the most significant bioclasts. Silicification of bioclasts and micrite matrix is the most important diagenetic event, whick creates the bulk of the micro-intercrystalline porosity. The recrystallization of micrite matrix and bioclasts into pseudospar, plus the cementing by later-stage carbonate and bitumen has totally occluded all the primary visible porosity in this limestone. The last five samples (#23, #24, #25, #29, #30) are from the siliceous shale dominated beds. These shales are highly carbonaceous (very fine carbonaceous partings), calcareous, dolomitic, locally highly siliceous and contain less bioclasts than the previously mentioned limestone. The SEM samples in this lower zone highlighted well to moderately interconnected micro-intercrystalline porosity in chert derived from silicified carbonate or shale. Healed tectonic fractures were observed in the drill cuttings of both upper limestone and lower shale dominated zones. Only trace quantities of visible intercrystalline and micro-vuggy porosity were observed in some of these samples. The most abundant and important pore type in terms of volume is micro-intercrystalline. The best volumes of micro-intercrystalline porosity occur in the most silicified beds (chert types 1 and 2). Poor to moderate volumes of micro-intercrystalline porosity occurs in partially silica replaced calcareous micrite (chert type 6). Often this micro-intercrystalline pore system is well interconnected on a microscale, however the small pore throat size and heterogeneity of silicification would lead to low permeability. The tectonic fracture system at this location if open downhole would act as permeability channels that would interlink zones of abundant

micro-intercrystalline porosity. In this study the reservoir quality of the matrix rock is poor in all samples. Reservoir quality of the L-68-60 well is mainly controlled by diagenesis (silicification of carbonate or shale, tectonic fracturing, carbonate cementation, plus to a lesser degree dolomitization and bitumen precipitation). The depositional environment is a less important reservoir quality factor because diagenetic cements have occluded all primary porosity. The following table summarizes the pore system and reservoir quality of each sample in this study.

Sample No.	Depth (m)	TS Por.	Pore Types	Amount and Degree of interconnectiveness of Microporosity (ϕ)	Main ϕ Controls	Reservoir Quality
2	1530 -1535	TR	Mixl, mV	high ϕ, poorly to mod. intct	cht, carb, dol, frac.	P, but with fractures
5	1545 -1550	TR	Mixl, mV	high ϕ, mod. intct	cht, carb, pyr, frac	P, but with fractures
8	1560 - 1565	TR	Mixl, Ixl, If	high ϕ, mod. to well intct	cht, carb, bit	P
11	1670 - 1675	TR	Mixl, Ixl, Ip	poor to mod. ϕ, poor to mod. intct	cht, carb, bit	P
14	1685 - 1690	TR	Mixl, Ixl	mod. to high ϕ, poor to mod. intct	cht, carb	P
17	1700 -1705	TR	Mixl	high ϕ, well intct	cht, carb, bit	P, but with fractures
19	1745 -1750	TR	Mixl	mod. ϕ, mod. intct	cht, carb	P
23	2340 - 2345	TR	Mixl, mV	high ϕ, mod. to well intct	cht, carb, frac	P, but with fractures
24	2370 - 2375	TR	Mixl	mod. ϕ, poor to mod. intct	cht	P
25	2375 - 2380	TR	Mixl	N/A	cht, carb	P
29	2880 - 2885	TR	Mixl, mV	mod. ϕ, mod. intct	cht	P
30	2885 - 2890	TR	Mixl	N/A	cht	P

Pore Types: Mixl – micro-intercrystalline, **Ixl** – intercrystalline, **mV** – micro-vug, **If** – intra-fossil, **Ip** – interparticle.
Permeability and Reservoir Quality: P – poor, **M** – moderate, **G** – good
Main Porosity (ϕ) Controls: cht – silicification, **Carb** – calcite or dolomite cements, **bit** - bitumen, **dol** – dolomite replacement, **frac** – tectonic fractures. **Abbreviations: mod.** – moderate, **intct** - interconnectiveness

The high amount of micro-intercrystalline porosity in the highly silicified beds of the Mississippian rock in this well suggests high portion of hydrocarbon (gas) storage potential. The small pore throats/opening and heterogeneous distribution of micro-intercrystalline porosity suggest that the pore system would be ineffective in regards to hydrocarbon production. However visible fracturing was observed in several samples in both the limestone (upper) and shale (lower) zones of the Mississippian of this well. If this tectonic fracturing is open downhole and significant in density they would act as permeability channels and help produce the potential hydrocarbon in the locally good micro-intercrystalline porosity.

Potential reservoir problems for the Mississippian in the L-68-60 location are as follows: 1) lack visible effective porosity, 2) acid sensitivity in regards to ferroan carbonate (dolomite and calcite) or pyrite (iron hydroxide gels) and bitumen (emulsion formation) and 3) replacement silica in carbonate could be dislodged from the rock fabric and become mobile under hydrochloric (HCl) acid treatment.

INTRODUCTION

This study describes the petrography, diagenesis and pore system of twelve samples of drill cuttings from the Mississippian at the Amoco S. Pointed Mountain (D-1) L-68-60-20-123-45 well. A brief summary of samples and analysis types used is given below. The purpose of the study was to determine the mineralogy, texture, diagenesis, reservoir quality and to determine the mechanism of hydrocarbon flow (pore system) in these apparently tight drill cuttings.

Sample No.	Depth (m)	Analysis Types
2	1530 - 1535	Thin Section, SEM
5	1545 - 1550	Thin Section, SEM
8	1560 - 1565	Thin Section, SEM
11	1670 - 1675	Thin Section, SEM
14	1685 - 1690	Thin Section, SEM
17	1700 - 1705	Thin Section, SEM
19	1745 - 1750	Thin Section, SEM
23	2340 - 2345	Thin Section, SEM
24	2370 - 2375	SEM
25	2375 - 2380	Thin Section
29	2880 – 2885	SEM
30	2885 - 2890	Thin Section

METHODS OF ANALYSIS

Ten drill cutting samples were sorted for proper lithology and then impregnated with blue epoxy to highlight porosity and other textural features. The thin sections were then stained with a combined Alizarin Red-S and potassium ferricyanide in order to differentiate calcite, ferroan calcite, dolomite, and ferroan dolomite. The thin sections were examined petrographically and point counted (200 points per section). Classification scheme used is based on depositional texture after DUNHAM (1962) with modifications of EMBRY and KLOVAN (1971). A petrographic summary, including framework mineralogy, matrix, diagenetic minerals, rock type, texture and porosity, is provided in Tables 1A to 1B. Ten scanning electron microscope (SEM) samples were also examined to highlight porosity, textures and to identify clay mineralogy. Representative thin section and SEM photomicrographs with descriptions, illustrating general and specific features of the sample, are provided in the appendix (Plate 1 to Plate 21).

PETROGRAPHIC DESCRIPTION AND INTERPRETATION

The Mississippian Age samples at the Amoco S. Pointed Mountain (D-1) L-68-60-20-123-45 well can be separated into two basic lithology types: siliceous limestone (samples 2, 5, 8, 11, 14, 17 and 19) and siliceous to carbonaceous shale (samples 23, 24, 25, 29 and 30). The limestone and shale lithology will be discussed separately with special attention paid to silicification and microporosity. Based on their textural characteristics, the **limestone** samples are grouped into three types: (1) wackestone/mudstone to grainstone (samples 2, 5 and 19 - Plates 1, 4 and 14), (2) mudstone to packstone (samples 8, 11 and 17 - Plates 6, 8 and 12) and 3) mudstone to wackestone (sample 14 - Plate 10). The wackestone/mudstone to grainstone are characterized partially by micro to coarse/very coarse crystalline limestone. The mudstone to packstone is characterized by more micrite and finer crystal size (micro to medium crystalline). The mudstone to wackestone sample is characterized by abundant micrite and scattered finely broken up bioclasts.

The wackestone/mudstone to grainstone samples (#2, #5, #19) consist predominantly of micrite (38% to 52%), with lesser amounts chert (15% to 17%), pseudospar calcite (10% to 19%), bioclasts (15% to 17%), ferroan dolomite (1% to 12% [sample 2 only]), plus minor ferroan calcite (1% to 4%), non-ferroan dolomite (4% to 5%), micritic dolomite (1% to 2%), micritic peloids (1% to 4% except sample 2) and quartz silt (trace to 1%). Pyrite (trace to 3%) replaces both micrite and sparry calcite. Trace carbonaceous material occurs in the micrite matrix. The mudstone to packstone samples (#8, #11 and #17) consist mainly of micrite (59% to 72%), with lesser amounts of pseudospar calcite (10% to 15%), bioclasts (4% to 9%), ferroan calcite (2% to 6%), ferroan dolomite (1% to 5% except sample 17), plus minor micritic peloids (trace to 1%), micritic dolomite (1% except sample 17) and bitumen (trace to 1%). Trace pyrite (1% in sample 11), organic material, and phosphate peloids (except sample 11) were also detected in these three samples. Sample 14 (mudstone to wackestone) consists of micrite (81%), with lesser amounts of chert (5%), bioclasts (6%), plus minor pseudospar calcite (3%), dolomite (2%), ferroan calcite (1%) and quartz silt (1%). Trace micritic peloids, micritic dolomite and ferroan dolomite is detected in sample 14.

Micrite is micro- to very fine crystalline anhedral calcite that occurs as the matrix that supports a bioclastic framework. Micrite also occurs in peloids, which is difficult to distinguish from the matrix. Micrite is occasionally replaced by dolomite rhombs (especially in sample 2, Plate 2). This micrite matrix is often partially to totally replaced by chert (Plate 1.3 and 12.3). Occasionally this micrite is recrystallized into mosaic pseudospar (Plate 12.4). Samples 11, 14 and parts of 17 have micrite that is rich in argillaceous material (Plates 10.3 and 10.4).

Bioclast suites are similar in all these samples with echinoid plates (Plate 1.4), ossicles (Plate 6.3) and spicules (Plate 4.1). Sponge spicules are the second most abundant bioclasts and are siliceous and often associated with chert (Plates 1.2, 4.2). Siliceous sponge spicules also float in more clay-rich calcareous matrix (Plate 8.2). Pelecypods and brachiopods (Plate 4.3) occur in all samples as well broken-up (reworked) shell fragments. Bryozoa fragments were observed in all samples except 11. This bryozoa and the less abundant coral fragments are recrystallized or cemented with pseudospar (Plate 4.3), ferroan calcite (Plate 6.4), ferroan dolomite and chert. Calcispheres (hard to distinguish bioclasts) occur in more clay-rich micrite. Rare Foraminifera float in fabric of samples 2 and 8. Coral fragments are found only in samples 5, 14 and 17. Rare Amphipora were found in samples 2 and 5 and rare ostracode shells were found in sample 19. Silicification of bioclasts is common in echinoid spicules (Plate 6.3), sponge spicules (recrystallized), brachiopod or pelecypod shell fragments (Plate 14.1). Foraminifera and coral (Plate 6.2) are occasionally altered to chert.

Diagenetic carbonate occurs as anhedral to subhedral dolomite (mostly slightly to highly ferroan), ferroan calcite, pseudospar and micritic dolomite. Ferroan and to lesser extent non-ferroan dolomite (Plate 2.1) occurs as floating rhombs in micrite which occasionally forms dolomite beds (sample 2 Photo 2.2). Ferroan dolomite (Plate 4.2) along with ferroan calcite (Plate 2.1) occlude micro-fractures. Ferroan calcite occurs mainly as subhedral cement that occludes intrafossil porosity (Plate 6.4), replace small bioclasts or replace micrite (Plate 8.3) and as late stage cement (Plate 14.4) postdating silicification. Pseudospar occurs as replacement of matrix micrite and as cement or recrystallization of bioclasts (Plate 14.2). Minor amount of micrite is altered to microcrystalline dolomite (except sample 17). Bitumen occurs as late stage intercrystalline embayment (Plate 14.4) in samples 8, 11 and 17. Bitumen stains and coats micro-intercrystalline porosity in chert (Plate 13.1). Diagenetic pyrite occurs as large framboids in pseudospar and as micro-framboids lining micro-intercrystalline porosity (Plate 13.3) in chert. Samples 2, 5 and 17 have tectonic fractures suggesting a downhole fracture network. All the microfractures are healed but open fractures are rarely preserved in drill cuttings. If this fracture system is open downhole they would act as permeability channels

Based on their textural characteristics, the **shale** samples are grouped into two types: (1) dark brown carbonaceous possibly siliceous shale and (2) silty shale. The detrital matrix (detrital clays and fine silts) dominates the mineralogy of this shale (78% to 90% by rock volume). The organic matter is generally silt sized (<44μm) and was group with detrital argillaceous material when point counted (to small to separate out). The EDX results from the SEM suggest that this shale contain significant amounts of calcite (micrite not distinguishable from the clay in thin section?). This dark brown carbonaceous shale contains moderate amounts of floating ferroan dolomite (1% to 6%), ferroan calcite (3% to 7% except for sample 30), non-ferroan dolomite (1% to 4%) and chert (1% to 4%). Bioclasts occur in minor quantities (1% to 5%) and consists of calcispheres, pelecypod shell fragments, echinoid ossicles and spicules (except sample 30), ostracode shells (except sample 23), foraminifera (except sample 30), brachiopods (except sample 30) and bryozoa (sample 25 only). The trace phosphate debris in sample 23 has possible bioclastic origin. The silty shale (Plate 21.2) is rich in medium size quartz silt, organic partings and floating ferroan dolomite rhombs. Trace to 1% micro-pyrite was observed in these samples.

Silicification is significant in these shale dominated beds. The SEM for sample 23, 24 and 29 are generally more siliceous than the upper more limestone beds as shown by the EDX results (dominated by silicon see Plates 17, 18 and 20). Thin section of sample 23 did not contain pure chert chips while the SEM consists of chert with scattered euhedral crystals (possible sponge spicules Plate 17.4) and well interconnected micro-intercrystalline and micro-vuggy pore system. In samples 24 and 29 the silicification is less complete (EDX shows more calcium and aluminum than what was found in sample 23) and often shows the fabric of original shale (Plate 18.1) or carbonate. The clay minerals detected by SEM are kaolinite, illite and possible smectite (mixed-layer with smectite). Samples 24 and 29 have poor to moderately interconnected micro-intercrystalline pore system. The SEM analysis shows that silica-rich zones of the lower portion of this well (shale zone) contain significant amounts of microporosity.

The evidence of tectonic fracturing is significant in the shale dominated section of this well. Sample 23 has chips of ferroan calcite cement that suggest fracture fill (Plate 16.1). These ferroan calcite chips show internal striations and possible displacement, which suggest fracture cement or gouge. In sample 30 relatively common polycrystalline quartz and chert healed fracture system is evident (Plates 21.3 and 21.4). If this fracture system are open downhole (drill cuttings rarely preserve open fractures) they would act as permeability channels.

Chert Classification

Alteration of original carbonate or shale to chert or polycrystalline quartz (silicification) occurs in different modes and morphologies. The differences depend on the completeness of silicification, crystal habit, amounts of micro-crystalline porosity, size of quartz subcrystals and the amount of remnant (clay or calcite) or diagenetic (bitumen and ferroan carbonate) impurities. The following list describes the diagentic chert/quartz found in this well.

1) Pure chert that replaced most to all the original carbonate (Plates 17.3 and 17.4). This pure chert is often associated with sponge spicule-rich beds (Plate 4.2) in the limestone section of this well. Various amounts of remnant interparticle micrite remain in these highly silicified beds. The chert has high volume of micro-intercrystalline and lesser micro-vuggy porosity. The interconnectiveness of the pore system is enhanced by the subhedral to euhedral crystal habit.

2) Patchy "dirty" light brown coloured chert that replaces matrix micrite (Plates 1.3 and 12.3) and bioclasts (Plate 6.3). This "dirty" chert has good micro-intercrystalline porosity that coated with late stage bitumen (Plate 13.1 and 13.4) or cemented with diagenetic pyrite (Plate 6.2). This chert type also has high volumes of microporosity.

3) Highly siliceous beds (in shale zone of well) with abundant remnant clay minerals (Plate 17.2 and 18.1). This chert appears to be the product of silica replacement of shale (originally possibly calcite-rich?). The volume of microporosity is less than what is found in chert that replaces pure carbonate (types 1 and 2). The crystal habit of this chert is anhedral to subhedral, which effects the interconnection and amounts microporosity.

4) The fourth kind of silica mineralization is the coarse crystalline chert or polycrystalline quartz that heal fractures (Plate 21.3 and 21.4). This coarse crystalline poly-quartz appears to be tight.

5) The recrystallization of siliceous bioclasts (sponge spicules and possible other bioclasts) to

microporous chert (Plate 4.4).

6) The partial silicification of micrite to anhedral micro-quartz that is evenly distributed in the calcareous micrite. Often the silica in the micrite is not observed in thin section. The silica content is confirmed in the SEM (example Plates 3 and 5) by EDX results and occasional suhhedral quartz crystals. This partially silicified micrite has poor to moderate volumes of micro-intercrystalline porosity (less that the types 1 and 2).

POROSITY AND PERMEABILITY

The drill cuttings from both the upper limestone (all samples < #19) and lower shale (samples 23, 24, 25, 29 and 30) show almost no visible porosity in thin section. However SEM analysis shows significant volumes of microporosity in the form of micro-crystalline and to lesser extent micro-vuggy porosity in partially to totally silicified beds. A few larger effective intercrystalline pores (Plate 5.1 approximately 20μm) were observed in SEM but not in thin section. The amount of micro-intercrystalline porosity in the partially silicified micrite (chert type 6) is generally smaller than the pure chert types 1 and 2. The following pore throat/openings were measured by SEM in these partially silicified micrite: sample 2: 1.5 to 2.0μm, sample 5: 3 to 5μm, sample 11: <1 to 8μm, sample 14: 1 to 4.5μm, and sample 19: 1.5 to 7μm. In contrast the volume of porosity in the more silicified beds (chert types 1 and 2) is generally greater than the previously mentioned partially silicified micrite. The following pore throat/openings were measured by SEM in purer cherts (types 1 and 2): sample 8: 2 to 6μm, sample 17: 1.2 to 7μm, and sample 23: 1 to 7μm. Although the pore size in chert types 1, 2 and 6 are similar the volume of larger pores is greater in the purer chert beds (types 1 and 2) when compared to partially silicified micrite bed (type 6). The chert type 3 (silicified shale or very argillaceous limestone) has moderate volumes of micro-intercrystalline and micro-vuggy porosity. The following pore throat/openings were measured in chert type 3: sample 23: 1 to 3.5μm, sample 24: 2 to 6μm, and sample 29: 2 to 5μm. Chert type 3 which formed by the silica replacement of calcareous shale tend to be poorly to moderately interconnected due more clay minerals and smaller heterogeneous pore system. The polycrystalline to chert fill (type 4) in fractures appears totally tight in thin section. None of this fracture fill polycrystalline quartz was observed in SEM. The chert replaced bioclasts (Type 5) probably have the same micro-intercrystalline porosity observed to chert types 1 and 2. It was impossible to distinguish chert derived from bioclast or matrix under the SEM.

The matrix in the silica-rich altered carbonates or shale has a significant volume of microporosity; which could hold large quantities of hydrocarbons (gas). This microporosity appears to be often well interconnected on the micro-scale (especially the purer chert type beds). However the pore throats/openings are very small resulting in low permeability. Also microporous chert or siliceous limestone zones are heterogeneously distributed within tight limestone, which further reduces the potential permeability of this reservoir. Significant evidence of fractures were observed through out this well (samples 2, 5, 17, 23 and 30). These fractures are occluded by various mineral fills (ferroan calcite, ferroan dolomite, poly to microcrystalline quartz and bitumen [sample 17]). It is very rare to see direct evidence of open fractures in drill cuttings; therefore it should not be a major concern that all fractures are healed. If these fractures are open down hole they would act as permeability channels which would interlink the microporous but low permeability zones of this reservoir.

RESERVOIR QUALITY AND FLUID SENSITIVITY

Reservoir quality of the Mississippian Age rock at the Amoco S. Pointed Mountain (D-1) L-68-60-20-123-45 well is mainly controlled by diagenesis (silicification of carbonate or shale, tectonic fracturing, carbonate cementation, plus to a lesser degree dolomitization and bitumen precipitation). The depositional environment is a less important reservoir quality factor because diagenetic cements have occluded all primary porosity. Depositional environment is important in regards to host rock for silicification. The micro-intercrystalline porosity appears to be greater in volume and interconnectiveness in diagenetic chert derived for carbonate (types 1 and 2) than calcareous shale (type 3). The following table summarizes the pore system and reservoir quality of each sample in this study.

Sample No.	Depth (m)	TS Por.	Pore Types	Amount and Degree of interconnectiveness of Microporosity (ϕ)	Main ϕ Controls	Reservoir Quality
2	1530 -1535	TR	Mixl, mV	high ϕ, poorly to mod. intct	cht, carb, dol, frac.	P, but with fractures
5	1545 -1550	TR	Mixl, mV	high ϕ, mod. intct	cht, carb, pyr, frac	P, but with fractures
8	1560 - 1565	TR	Mixl, Ixl, If	high ϕ, mod. to well intct	cht, carb, bit	P
11	1670 - 1675	TR	Mixl, Ixl, Ip	poor to mod. ϕ, poor to mod. intct	cht, carb, bit	P
14	1685 - 1690	TR	Mixl, Ixl	mod. to high ϕ, poor to mod. intct	cht, carb	P
17	1700 -1705	TR	Mixl	high ϕ, well intct	cht, carb, bit	P, but with fractures
19	1745 -1750	TR	Mixl	mod. ϕ, mod. intct	cht, carb	P
23	2340 - 2345	TR	Mixl, mV	high ϕ, mod. to well intct	cht, carb, frac	P, but with fractures
24	2370 - 2375	TR	Mixl	mod. ϕ, poor to mod. intct	cht	P
25	2375 - 2380	TR	Mixl	N/A	cht, carb	P
29	2880 - 2885	TR	Mixl, mV	mod. ϕ, mod. intct	cht	P
30	2885 - 2890	TR	Mixl	N/A	cht	P

Pore Types: Mixl – micro-intercrystalline, **Ixl** – intercrystalline, **mV** – micro-vug, **If** – intra-fossil, **Ip** – interparticle.
Permeability and Reservoir Quality: P – poor, **M** – moderate, **G** – good
Main Porosity (ϕ) Controls: cht – silicification, **Carb** – calcite or dolomite cements, **bit** - bitumen, **dol** – dolomite replacement, **frac** – tectonic fractures.
Abbreviations: mod. – moderate, **intct** – interconnectiveness

In this study the reservoir quality of the matrix rock is poor in all samples. The high amount of micro-intercrystalline porosity in the highly silicified beds of the Mississippian rock in this well suggests high portion of hydrocarbon (gas) storage potential. However the SEM indicate that the small pore throats/opening and heterogeneous distribution of micro-intercrystalline porosity would suggest that the pore system is ineffective in regards to hydrocarbon production. However visible fracturing was observed in several samples in both the limestone (upper) and shale (lower) zones of the Mississippian of this well. If this tectonic fracturing is open downhole and significant in density they could act as permeability channels and help produce the potential hydrocarbon in the local good micro-intercrystalline porosity.

Potential reservoir problems for the Mississippian in the L-68-60 location are as follows: 1) lack visible effective porosity, 2) acid sensitivity in regards to ferroan carbonate (dolomite and calcite) or pyrite (iron hydroxide gels) and bitumen (emulsion formation) and 3) replacement silica in carbonate could be dislodged from the rock fabric and become mobile under hydrochloric (HCl) acid treatment. Trace fresh water sensitive smectite (generally as mixed layer illite/smectite) was observed in the shale zone of this well, but not in significant amounts to be a reservoir problem.

Hydrochloric acid (HCl) reacting with bitumen may form sludges or viscous emulsions, which can restrict permeability potential. Both sludges and emulsions may be removed by using appropriate surfactants (surface active agents), which reduce interfacial and surface tension and result in a more miscible mixture of oil and water (acid). Sequestering agents and oxygen scavengers could be used to control the precipitation of iron hydroxide gels in an acid treatment.

The effectiveness of natural fractures can possibly be enhanced by fracture stimulation to improve the reservoir deliverability. An iron-sequestering agent could be used to prevent iron hydroxide gel precipitation.

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Table 1A
Petrographic Summary of Drill Cutting Samples from the Mississippian at the Amoco S. Pointed Mountain (D-1) L-68-60-20-123-45 Well

	2 1530-35m	5 1545-50m	8 1560-65m	11 1670-75m	14 1685-90m
FRAMEWORK & MATRIX					
Micrite	38	38	68	59	81
Calcite (Pseudospar)	10	19	11	10	3
Quartz Silt / Sand	1	1	TR	1	1
Peloids	-	4	-	1	TR
Organic Material	TR	TR	-	TR	-
Bioclasts	15	15	9	8	6
Crystal Texture	anh - sub	anh - sub	anh - sub	anh	anh
CEMENT					
Ferroan Calcite	1	3	4	6	1
Ferroan Dolomite	12	1	1	5	TR
Dolomite	5	4	2	1	2
Micrite Dolomite	2	2	1	1	TR
Chert/Polyxl Quartz	14	13	3	6	5
BIOCLASTS (Breakdown)					
Echinoids	5	4	4	2	2
Sponge Spicules	5	4	4	2	2
Brachiopods	1	1	TR	2	-
Pelecypods	2	2	TR	2	TR
Bryozoa	1	2	1	-	TR
Others	1	2	TR	-	2
OTHER CONSTITUENTS					
Pyrite	2	3	TR	1	1
Phospate	TR	1	TR	-	TR
Argillaceous materials	-	-	-	TR	TR
Bitumin	-	-	1	1	-
ROCK TYPE	Dol/Cht LS	Cht LS	LS	Arg LS	Arg LS
ORIGINAL TEXTURE	WS - GS	WS - GS	MS - PS	MS - PS	MS - WS
HEALED FRAC.	YES	YES	NO	NO	NO
POROSITY					
Pore Types	Mixl	Mixl	Mixl, Ixl	Mixl	Mixl
Vug Diameter [μm]	-	-	-	-	
CORE POROSITY [%]	N/A	N/A	N/A	N/A	N/A
TS POROSITY [%]	TR	TR	TR	TR	TR
PERMEABILITY [mD]	N/A	N/A	N/A	N/A	N/A
RES. QUALITY	P	P	P	P	p

Original Texture: MS - Mudstone, **WS** - Wackestone, **PS** - Packstone, **GS** - Grainstone

Porosity Types: Ixl - Intercrystalline, **Mixl** - Micro-intercrystalline, **MP** - Micro-porosity

Table 1B
Petrographic Summary of Drill Cutting Samples from the Mississippian at the Amoco S. Pointed Mountain (D-1) L-68-60-20-123-45 Well

	17 1700-05m	19 1745-50m	23 2340-45m	25 2375-80m	30 2885-90m
FRAMEWORK & MATRIX					
Micrite	72	52	2	TR	-
Calcite (Pseudospar)	15	14	3	-	-
Quartz Silt / Sand	TR	TR	TR	1	3
Peloids	TR	1	-	-	-
Organic Material	TR	TR	TR	TR	TR
Bioclasts	4	17	3	5	1
Crystal Texture	anh	anh - sub	anh	anh	anh
CEMENT					
Ferroan Calcite	2	4	3	7	-
Ferroan Dolomite	-	1	6	1	1
Dolomite	4	4	2	4	1
Micrite Dolomite	-	1	-	-	-
Chert/Polyxl Quartz	7	7	3	1	4
BIOCLASTS (Breakdown)					
Echinoids	2	6	TR	3	-
Sponge Spicules	TR	2	-	-	-
Brachiopods	-	2	TR	TR	-
Pelecypods	1	1	2	1	TR
Bryozoa	1	-	-	1	-
Others	-	6	1	TR	1
OTHER CONSTITUENTS					
Pyrite	TR	TR	TR	1	TR
Phospate	TR	-	TR	-	-
Argillaceous materials	TR	TR	78	80	90
Bitumin	TR	-	TR	-	-
ROCK TYPE	LS	Cht LS	SH	SH	SH
ORIGINAL TEXTURE	MS - PS	WS - GS	N/A	N/A	N/A
HEALED FRAC.	YES	NO	YES	NO	YES
POROSITY					
Pore Types	Mixl	Mixl	MP	MP	MP
Vug Diameter [μm]	-	-	-	-	-
CORE POROSITY [%]	N/A	N/A	N/A	N/A	N/A
TS POROSITY [%]	TR	TR	TR	TR	TR
PERMEABILITY [mD]	N/A	N/A	N/A	N/A	N/A
RES. QUALITY	P	P	P	P	P

Original Texture: MS - Mudstone, **WS** - Wackestone, **PS** - Packstone, **GS** - Grainstone

Porosity Types: Ixl -Intercrystalline, **Mixl** - Micro-intercrystalline, **MP** - Micro-porosity

LIST OF ABBREVIATIONS

FAUNA

Bry	-	BRYOZOAN
Ech	-	ECHINODERM
Bra	-	BRACHIOPOD
Os	-	OSTRACOD
Cal	-	CALCISPHERES
Biocl	-	BIOCLASTS
Biv	-	BIVALVE
Moll	-	MOLLUSK
Foram	-	FORAMINIFERA
Strom	-	STROMATOPOROID
Cor	-	CORAL
Ga	-	GASTROPOD
Pele	-	PELECYPOD

CRYSTAL TEXTURE

Euh	-	EUHEDRAL
Sub	-	SUBHEDRAL
Anh	-	ANHEDRAL

ORIGINAL TEXTURE

DOLOGS	-	DOLOGRAINSTONE
DOLOPS	-	DOLOPACKSTONE
DOLOWS	-	DOLOWACKESTONE
DOLOMS	-	DOLOMUDSTONE
DOLOFS	-	DOLOFLOATSTONE
DOLORS	-	DOLORUDSTONE

GRAIN TYPES

Pel	-	PELOID

GRAIN SIZE

Cxl	-	COARSE CRYSTALLINE
Mxl	-	MEDIUM CRYSTALLINE
Fxl	-	FINE CRYSTALLINE
Vfxl	-	VERY FINE CRYSTALLINE

POROSITY TYPES

Mixl	-	MICROINTERCRYSTALLINE
Ixl	-	INTERCRYSTALLINE
Mo	-	BIOMOLDIC
mV	-	MICROVUGGY
mF	-	MICROFRACTURE
Ig	-	INTERGRANULAR
IP	-	INTERPARTICLE

QUALITY

G	-	GOOD
M	-	MODERATE
P	-	POOR

CEMENT TYPES

Syn	-	SYNTAXIAL OVERGROWTHS
Blo	-	BLOCKY
Poik	-	POIKILOTOPIC
Dru	-	DRUSY
SD	-	SADDLE DOLOMITE
Lath	-	ANHYDRITE LATHS
Grm	-	GROUNDMASS
Iso	-	ISOPACHOUS RIMS
Spa	-	SPARITE
Rhomb	-	RHOMBIC

APPENDIX

Thin Section and SEM Photomicrographs and Descriptions (Plates 1 to 21)

(All thin section pictures are taken generally under plane-polarized light conditions except for Plate 21.4 which is under cross polarized light)

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 1
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

DOLOMITIC/CHERTY LIMESTONE (WACKESTONE TO PACKSTONE)

Porosity: N/A **Permeability: N/A**

Sample #2: 1530 - 1535m

1 Low magnification view of a micro- to very coarse crystalline bioclastic wackstone to packstone that is partially replaced by silica (forming chert) and dolomite rhombs. Pyrite framboids replacing carbonate are locally common. The bioclasts in this carbonate are echinoid spicules, plates or ossicles (F4), plus possible sponge spicules, pelecypod or brachiopod shell fragments, bryozoa, foraminifera, and Amphipora. These grains are cemented locally by calcite spar, chert and dolomite (ferroan [turquoise H4] and lesser non-feroan). The dolomite appears to generally replace micrite while chert replaces both bioclasts and matrix micrite. The light coloured chip (E10) in this view is almost completely replaced by chert. No visible porosity was detected in this thin section but micro-intercrystalline was seen in SEM. **x12.5 ppl**

2 Higher magnification view showing extensive silica replacement of a chip rich in sponge and/or echinoid spicules (white D6, I5) to chert. The high silica content of sponge spicules is the original source of silica. The matrix between these spicules is calcareous micrite. **x100ppl**

3 Higher magnification views showing the matrix micrite totally replaced by chert (light mottled brown M7). Echinoid plates and ossicles (M10) and a foraminifera (P4) are the framework bioclasts in this view. A late stage ferroan dolomite rhombs (turquoise I6) occur floating in the chert matrix or along the boundaries of bioclasts. A thin stylolite parting (F3 to K14) bisect this chip and is evidence of overburden pressure solution. **x100ppl**

4 A close up of limestone packestone with bioclasts (echinoid plates [L9], ossicles [L3] and spicules [G3], plus pelecypod shell [E1]] in matrix (I6) of micrite and silt size fossiliferous debris. **x50ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45 A10002
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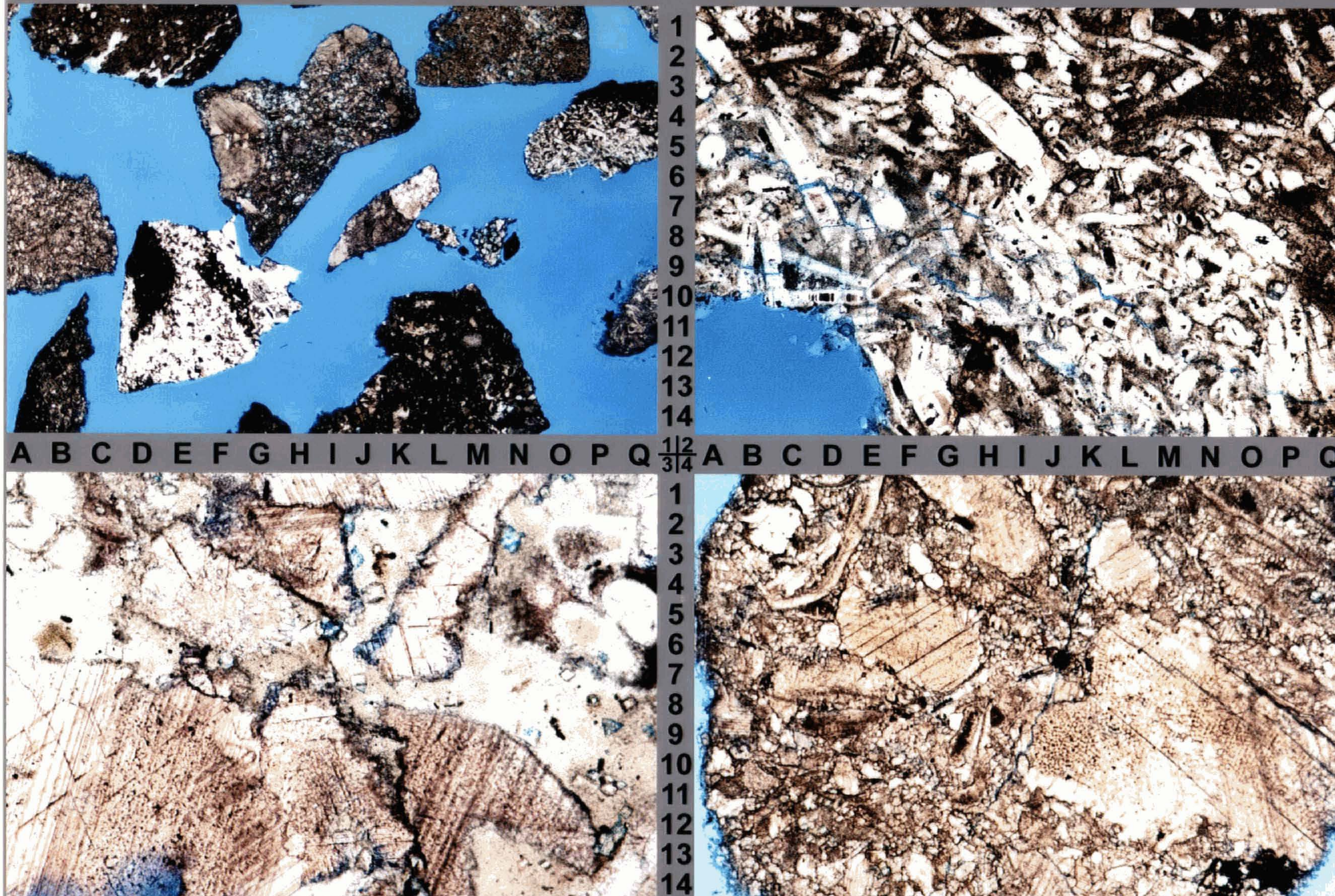

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PLATE #1
SAMPLE #2: 1530-1535m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 2
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

DOLOMITIC/CHERTY LIMESTONE (WACKESTONE TO PACKSTONE)

Porosity: N/A

Permeability: N/A

Sample #2, 1530 - 1535m

1 High magnification view of a micritic wackestone partially replaced by abundant dolomite rhombs (G1, G7). These subhedral dolomite rhombs float in non-altered micrite (pink G6). A sparry calcite healed microfracture (E1 to M14) bisects the fabric of this chip. An indistinct bioclast (N11) is totally replaced by pseudospar. **x100ppl**

2 High magnification view of chip that is almost totally replaced by slightly ferroan dolomite (O5). Minor very thin bituminous carbonaceous partings (black E13) bisect this dolomitic chip. Potential micro-intercrystalline porosity is greater in the highly dolomitized chips than in non-altered limestone chips. Very thin bituminous partings (black D13) show preferential orientation and appear to be deformed the result of pressure solution. **x100ppl**

1	2
3	4

2 mm	500 µm	250 µm	125 µm
x12.5	x50	x100	x200

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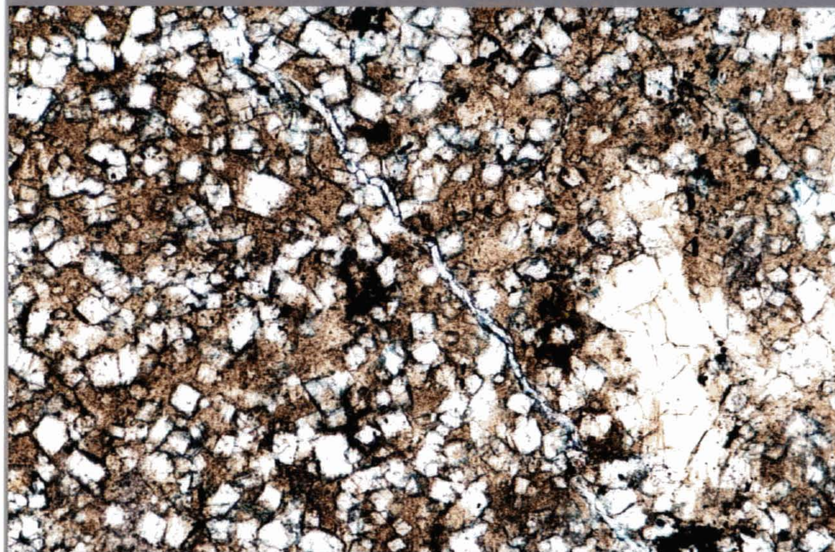

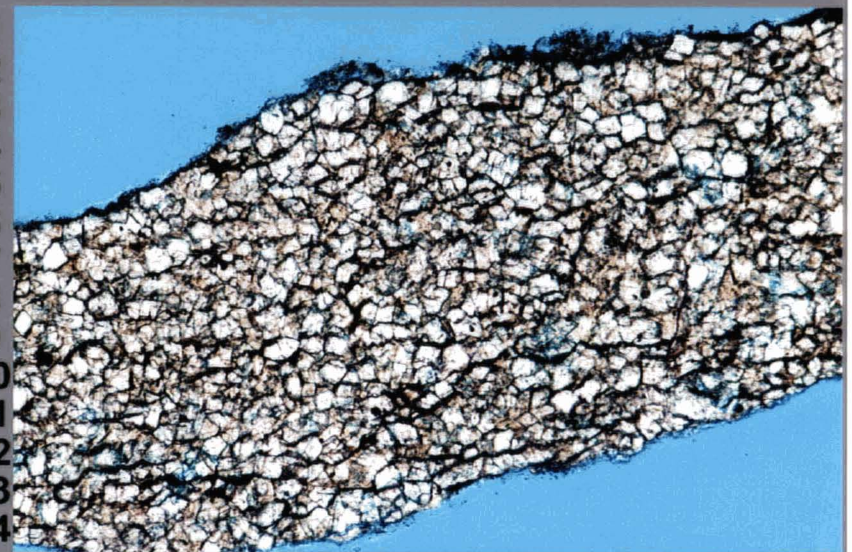

1 2 3 4 5 6 7 8 9 10 11 12 13 14

A B C D E F G H I J K L M N O P Q 1|2 3|4 A B C D E F G H I J K L M N O P Q

1 2 3 4 5 6 7 8 9 10 11 12 13 14

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PLATE #2
SAMPLE #2: 1530-1535m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 3
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

DOLOMITIC/CHERTY LIMESTONE (WACKESTONE TO PACKSTONE)

Porosity: N/A

Permeability: N/A

Sample #2, 1530 - 1535m

1 - 4 A series of very high magnification views highlighting the microporosity in silica rich limestone. Note the relatively large volume of micro-interystalline porosity (1:I10, 2:H7, 3:J6, 4:K10). The visible pore throats of this micro-intercrystalline pores are small as shown by these examples: 1.5μm (1:O-N7), 2μm (2:H7, 3:J6), and 1.8μm (4:K10). A few of these pores (1:D5) are larger and range up to 6μm (1:D5) and are considered micro-vugs. Minor amounts of illite ribbons (1:K10, 2:I7) and detrital kaolinite (2:F1, 3:P8) occur in siliceous carbonate. The typical EDX reading (relative counts per 20 sec) on these chips is as follows: Ca 351, Si 152, Al 30, Fe 24, and Ti 18. This EDX reading suggest carbonate micrite partially replaced by microporous chert. These crystals as anhedral and poorly developed. The more silica-rich view seen in photo 4 has the best and cleanest pore system. Overall this micro-intercrystalline porosity is poorly to moderately interconnected. **x3000, x3000, x3000, x5000**

1	2
3	4

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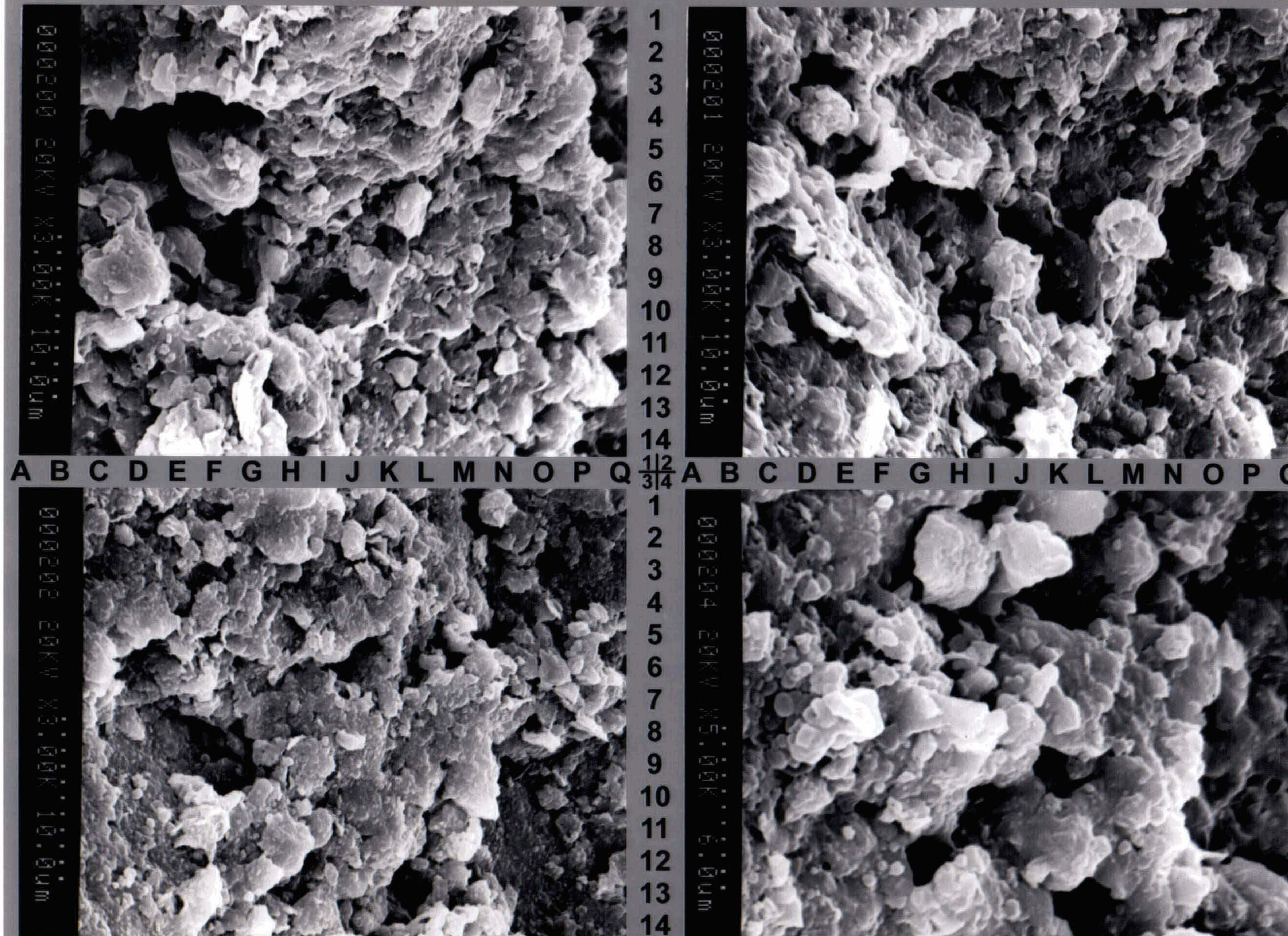

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PLATE #3
SAMPLE #2: 1530.00-1535.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 4
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (WACKESTONE TO PACKSTONE)

Porosity: N/A **Permeability: N/A**

Sample #5: 1545 - 1550m

1 Moderate magnification view of a micro- to coarse crystalline bioclastic wackstone to packstone that is partially replaced by silica (forming chert). Minor amounts of diagenetic pyrite floating in the fabric of this limestone. The bioclasts in this carbonate are echinoid spicules (L2), plates (D7) or ossicles (F4), plus sponge spicules, pelecypod or brachiopod shell fragments (J11), bryozoa (O11), coral and Amphipora. Local micritic peloids (L5) are additional framework grains. These grains are cemented locally by calcite spar (Q9) and lesser amounts of dolomite (mostly non-feroan L10). Chert replaces both matrix and framework bioclasts. The wackestone chips (not in view) are rich in matrix micrite. No visible porosity was detected in this thin section but micro-intercrystalline was seen in SEM. **x50 ppl**

2 Higher magnification view showing a chip totally (upper half) to partially (lower half) replaced by chert (mottled white). As with sample 2 the most siliceous chips are rich in sponge spicules (B11). A ferroan dolomite (turquoise) healed micro-fracture (I1 to N12) bisects this chert chip. **x100ppl**

3 Higher magnification view showing a close up of a bryozoa (L7) fragment with intrafossil pores totally cemented with calcite spar (pink 3:J9) and bitumen stained chert (C9). Anhedral dolomite rhombs (H6) and trace micro-pyrite (3:C9) are precipitated into the intra-fossil and matrix chert. Note the portion of the brachiopod (P13) in the upper right hand corner of this view. **x100ppl**

4 A high magnification view elongate subhedral quartz crystals (G3, K12) floating in mosaic limestone (recrystallized micrite). This neddle-like quartz have possible sponge spicule origin. Chert replaced echinoid ossicles (4:C1) were also detected. Dolomite rhombs (bioclastic nuclei) also float in the calcite (J4). **x100ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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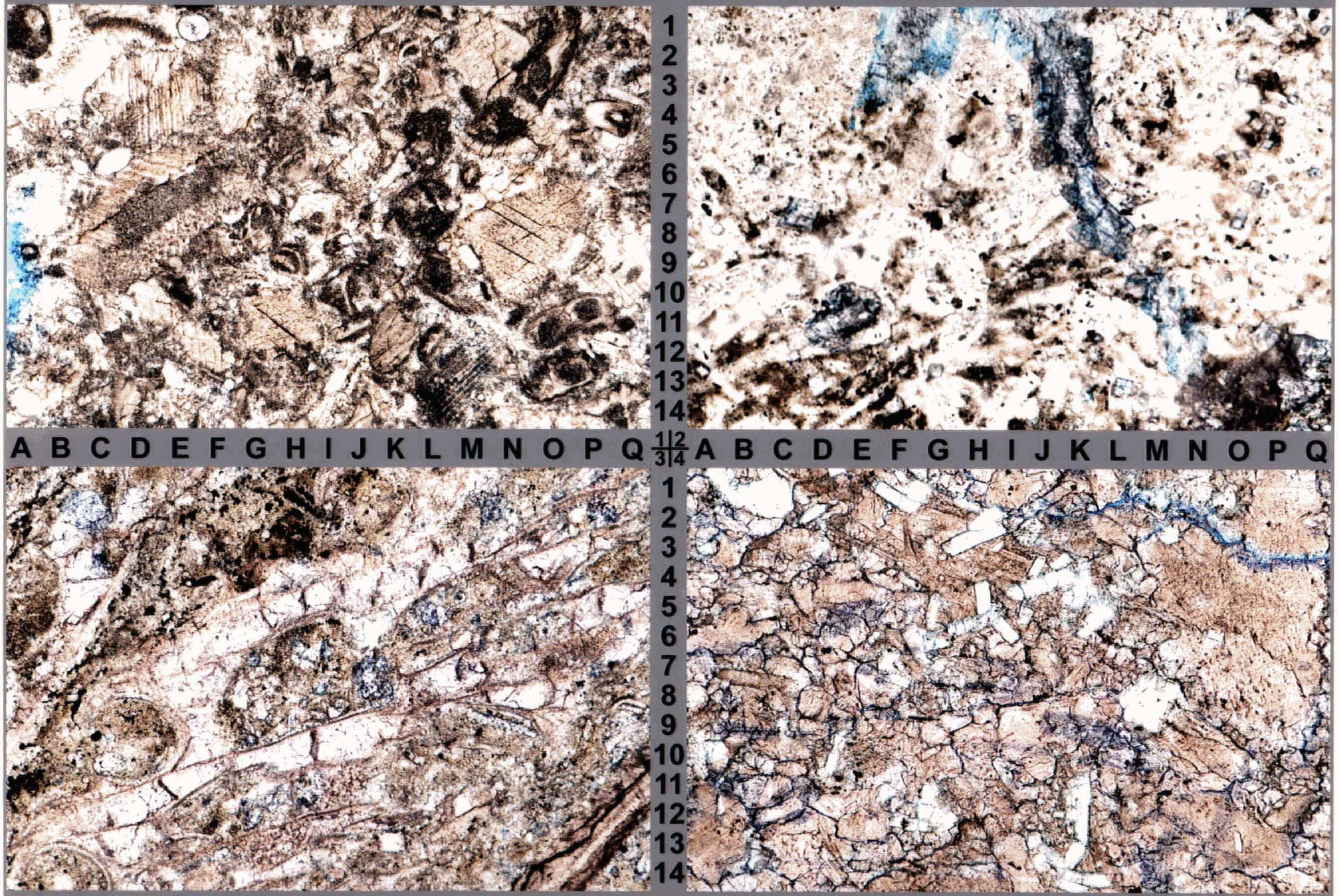

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PLATE #4
SAMPLE #5: 1545-1550m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 5
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (WACKESTONE TO PACKSTONE)

Porosity: N/A **Permeability: N/A**

Sample #5, 1545 - 1550m

1 - 4 A series of very high magnification views highlighting the microporosity in partially siliceous anhedral limestone. Note the relatively large volume of micro-interystalline porosity (2:M9, 3:H10, 4:L3). The visible pore throats of this micro-intercrystalline pores are small but larger than most of sample 2 as shown by these examples: 4.5µm (2:I2), 3µm (3:J6), and 5.0µm (1::D8, 4:J7). A few of these pores (1:L7) are larger and range up to 20µm (1:D5) and are considered intercrystalline or micro-vugs. Trace quantities of illite or kaolinite clays (2:J-I10, 3:F10) are intermixed into this carbonate. The typical EDX reading (relative counts per 20 sec) on these chips is as follows: Ca 610, Si 152, Al 75, Fe 32, and K 30. This EDX reading suggest carbonate micrite partially replaced by microporous chert (less so than sample 2). The presence of potassium (K) is partially due to cleaning the samples in KCl. These crystals as anhedral and poorly developed. Minor amounts of subhedral micro-quartz (3:K10) is clearly visible. Overall this micro-intercrystalline porosity is moderately interconnected but actual matrix permeability is low due to small very small pore size. **x300/x3000, x3000, x3000, x5000**

1	2
3	4

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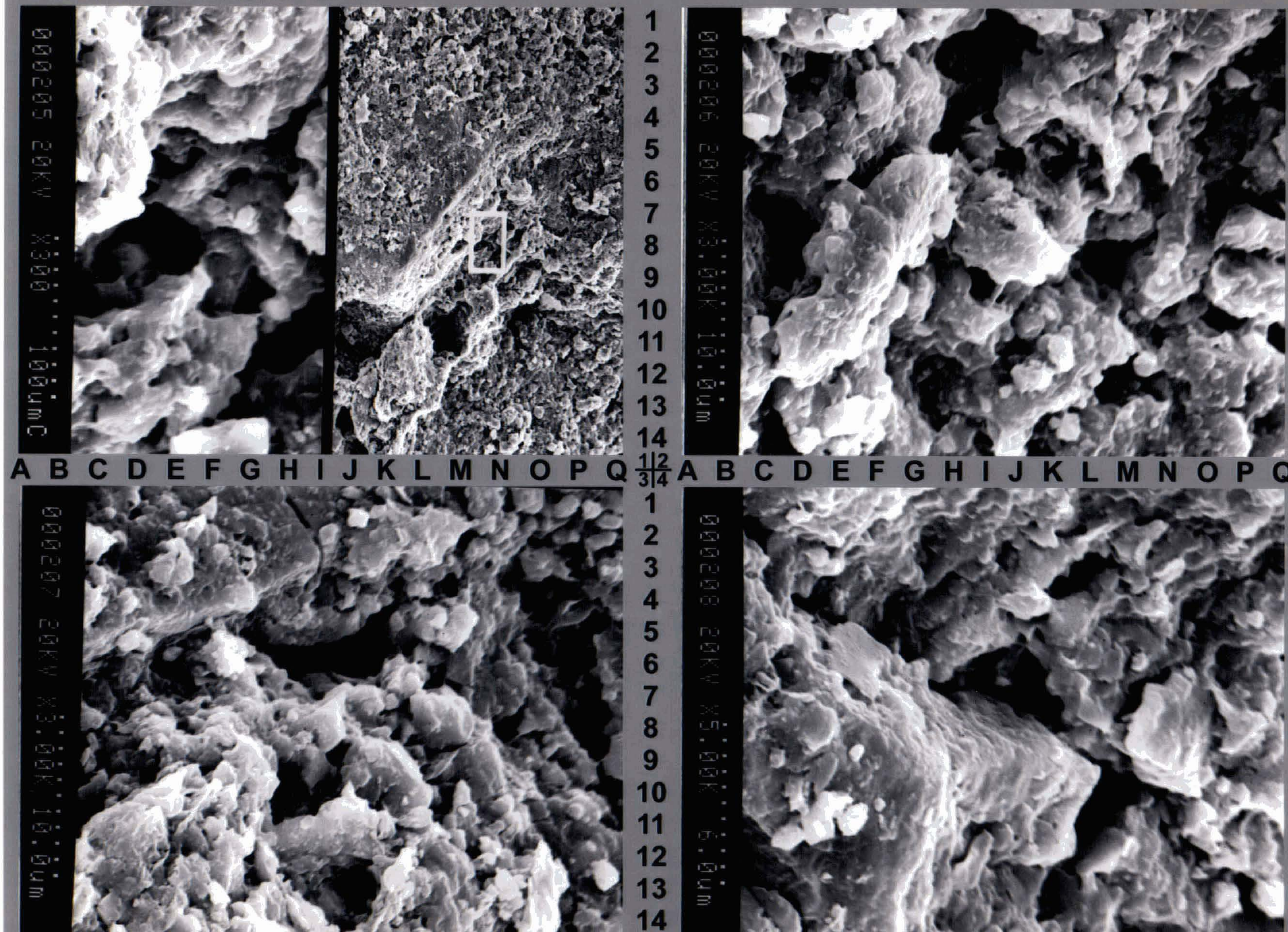

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PLATE #5
SAMPLE #5: 1545.00-1550.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 6
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A **Permeability**: N/A

Sample #8: 1560 - 1565m

1 A high magnification view of chips consisting of siliceous (chert replaced) sponge spicules (white) flowing in slightly argillaceous micrite matrix. Overall this sample is micro- to coarse crystalline bioclastic wackestone to packstone that is partially replaced by silica (forming chert) and dolomite (ferroan and non-ferroan). The bioclasts are echinoid spicules, plates or ossicles, plus sponge spicules (D12), bryozoa, plus trace pelecypod or brachiopod shell fragments (J11) and foraminifera. These grains are cemented locally by calcite spar, ferroan calcite, dolomite (non-ferroan and ferroan). Small quantities of the micrite has been altered to dolomite. Chert replaces mostly framework bioclasts. Trace visible intercrystalline porosity was detected. Micro-crystalline porosity is seen in SEM. **x100 ppl**

2 Moderate magnification view showing a highly altered bioclast replaced by pseudospar calcite (pink G4), plus later stage chert (E5) and pyrite framboids (black). This bioclast is surrounded by recrystallozed micrite (pink H2). **x50ppl**

3 Higher magnification view showing a bryozoa (H7), echinod spicules (O5) and ossicles (B6) floating in micrite matrix (pink). One of the echinoid ossicles (L6) is replaced by chert (microporosity plugs with bitumen?). **x100ppl**

4 High magnification view of large bryozoa fragment with the intra-fossil pores totally occluded by ferroan calcite (blue I13). The intercrystalline porosity in the micrite is totally occluded bitumen (black O4). Indistinct ferroan dolomite (?) occurs in this micrite (P4). **x100ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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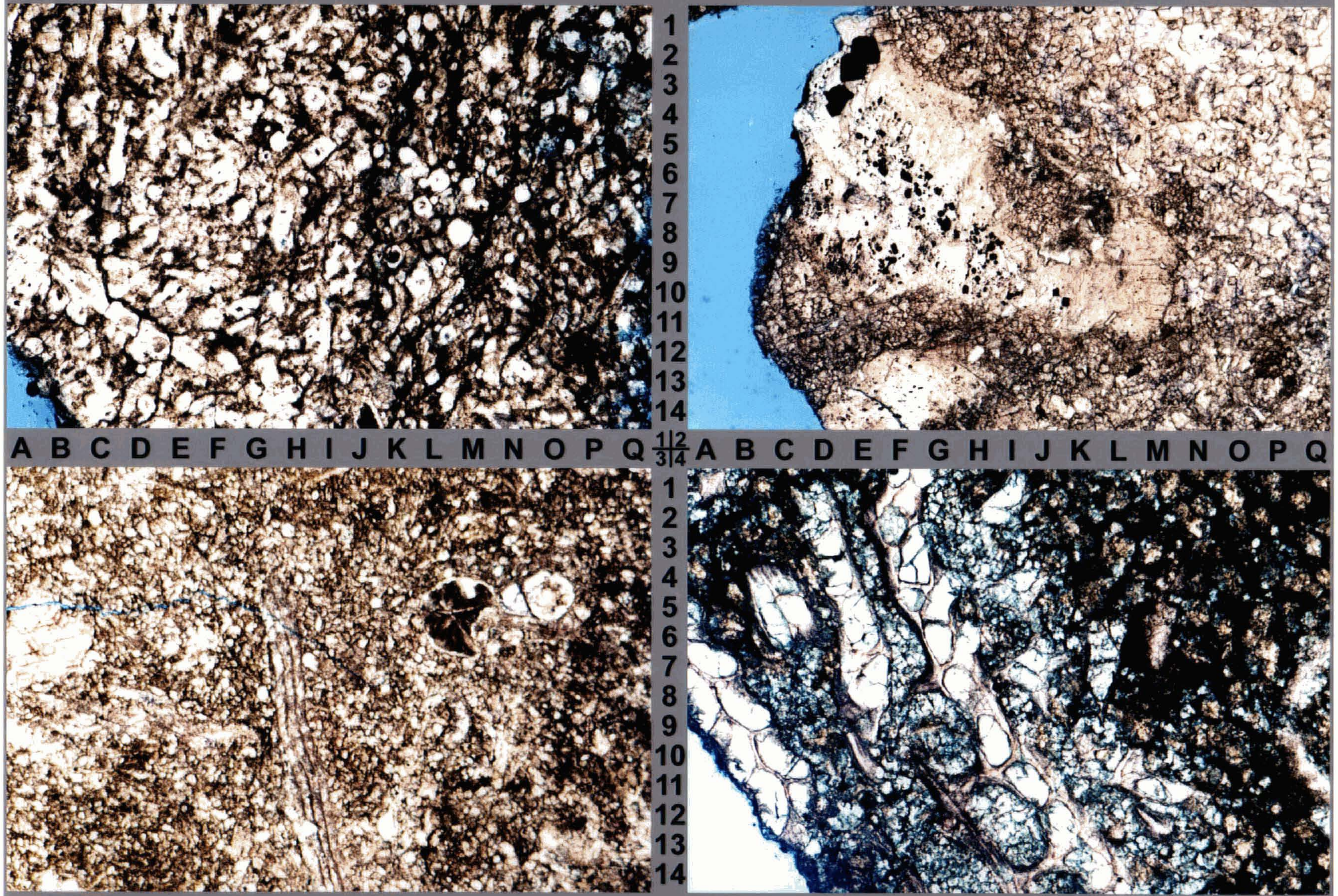

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PLATE #6

SAMPLE #8: 1560-1565m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 7
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A

Permeability: N/A

Sample #8, 1560 - 1565m

1 - 4 A series of very high magnification views in more siliceous limestone than the previous samples 2 and 5. The typical EDX reading (relative counts per 20 sec) on these chips is as follows: Ca 78, Si 135, Al 30, Fe 46, K 13, Ti 14 and Mg 15. This EDX reading suggests a highly chert replaced carbonate. Note the relatively large volume of micro-interystalline porosity (1:E4, 2:E8, 3:G4, 4:E8). Minor intra-fossil porosity (1:M6, 5μm) is found in siliceous micro-fossils (Foraminifera or diatom?). The visible pore throats of this micro-intercrystalline pores range as follows: 2μm (1:L3), 4μm (2:D8J6), 6μm (3:L87) and 3μm (4:L8). Minor amounts of kaolinite (2:F8, 4:J3) booklets and illite ribbons (3:F11) are intermixed with this siliceous carbonate (clays are indicate by aluminum and potassium in the EDX). These crystals are anhedral and poorly developed. Overall this micro-intercrystalline porosity is moderately to well (photo 2) interconnected but actual matrix permeability is low due to very small pore size. **x3000, x3000, x3000, x5000**

1	2
3	4

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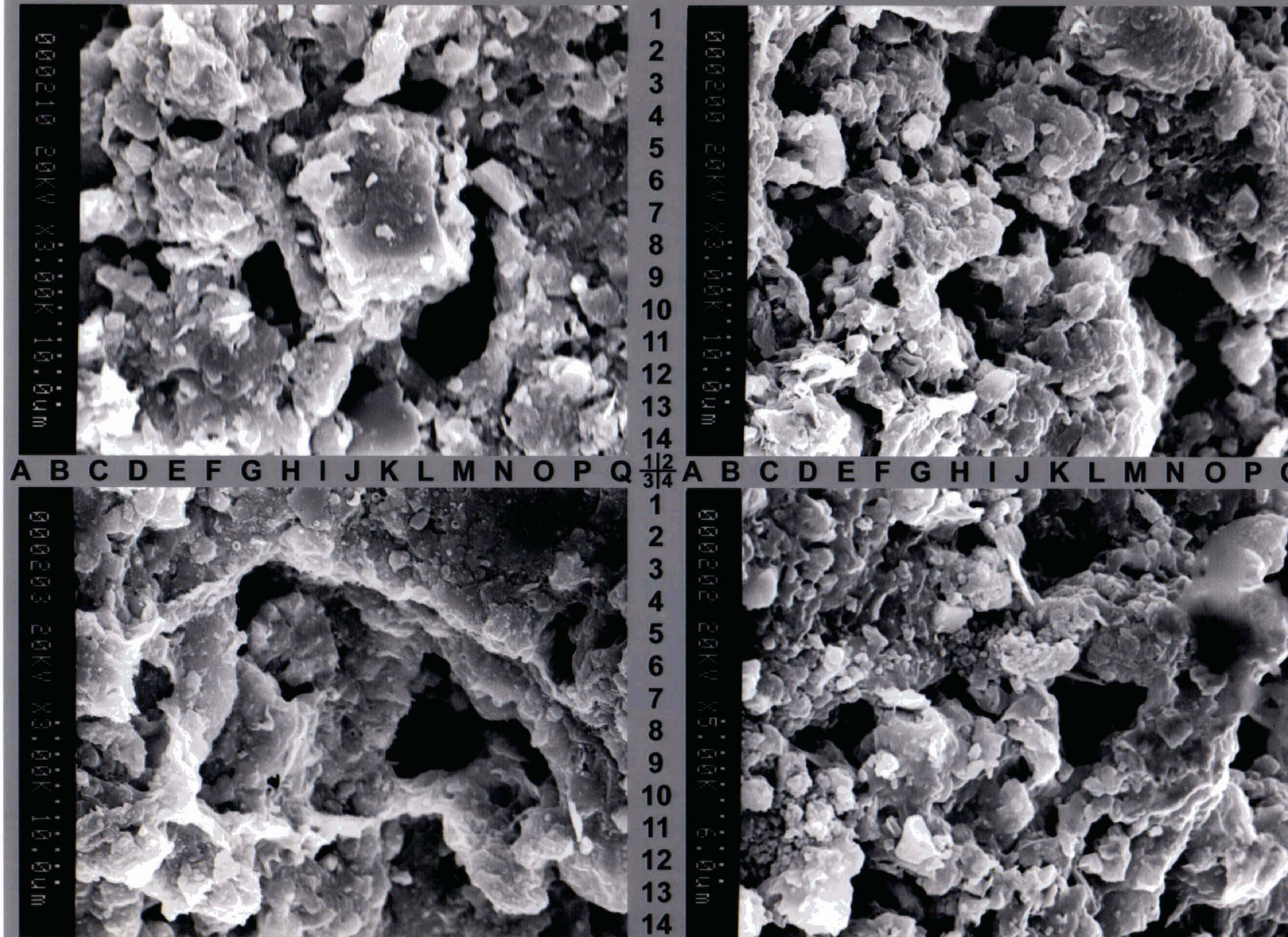

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PLATE #7
SAMPLE #8: 1560.00-1565.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 8
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

ARGILLACEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A **Permeability: N/A**

Sample #11: 1670 - 1675m

1 Low magnification view of a micro- to medium crystalline bioclastic mudstone to packstone that is partially replaced by silica (forming chert C8) and minor micritic dolomite. Some of the micrite is rich in argillaceous material (darl brown chips), Pyrite framboids locally replace argillaceous micrite. The bioclasts in this carbonate are brachiopod and pelecypod shell fragments, sponge spicules (C8), plus echinoid plates or ossicles. These grains are cemented locally by calcite spar, ferroan calcite and dolomite (mostly ferroan). No visible porosity was detected in this thin section but micro-intercrystalline pores were seen in SEM. **x12.5 ppl**

2 Moderate magnification view of packstone with well broken-up bioclast fragments (brachiopod or pelecypod shell fragments [C6], pseudospar replaced echinoid ossicles [D1] floating in the matrix of micrite (pink) rich with bituminous organic partings (black G13). **x50ppl**

3 Higher magnification views showing the ferroan calcite (light blue H3) cementing possible intrafossil pores and replacing micrite (possible small fossil nuclei). Wispy carbonaceous argillaceous partings (B13 to Q9) bisect this chip. Trace bitumen (black M3) and micro-pyrite framboids (black Q13) plug intercrystalline pores. **x100ppl**

4 Higher magnification of clay-rich micritic (brown) wackestone with floating quartz or chert replaced sponge spicules (L6, O10). Note the scattered pyrite framboids (black O5) and rare ferroan dolomite rhombs (B-C9) floating in the fabric of this argillaceous wackestone. **x100ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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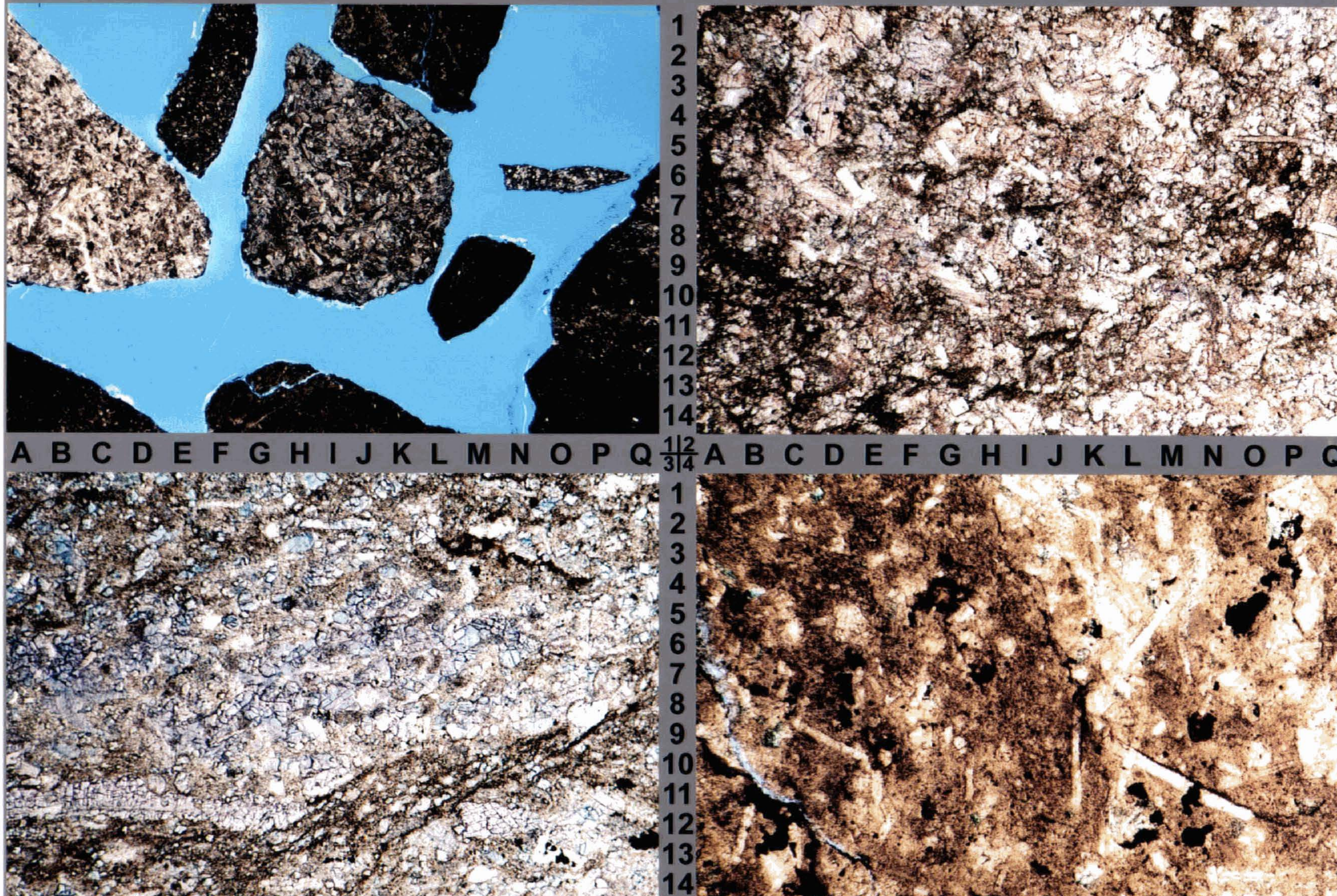

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PLATE #8
SAMPLE #11: 1670-1675m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 9
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

ARGILLACEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A

Permeability: N/A

Sample #11, 1670 - 1675m

1 - 4 A series of very high magnification views in limestone that is only moderately replaced by silica. The typical EDX reading (relative counts per 20 sec) of these chips is as follows: Ca 536, Si 198, Al 30, Fe 37 and K 21. Note that the volume of micro-intercrystalline pores (2:J7, 3:L6) in most of these chips is noticeable less than sample 8. These micro-intercrystalline pores range in size from <1.0μm (2:P5, 3:P7) up to 8.0μm (1:I6). This larger pore appears to be an interparticle pore. The majority of the matrix calcite in this sample is dense and non-porous (1:L11, 2:G5). Detrital clays are intermixed with this carbonate and consist of illite (3:F9, 4:J4) and kaolinite (3:F13). Photo 4 is a closer view of chip with better micro-crystalline porosity (4:L3). This micro-crystalline porosity is small and in the 1.2μm (4:L8, J14) to 1.0μm (4:F9) range. The view in photo 4 shows more subhedral quartz crystals (N11, H8) which result in greater porosity they photos 1 to 3. Overall this micro-intercrystalline pore system is poorly to moderately interconnected, but actual matrix permeability is low due to small very small pore size. **x3000, x3000, x3000, x5000**

1	2
3	4

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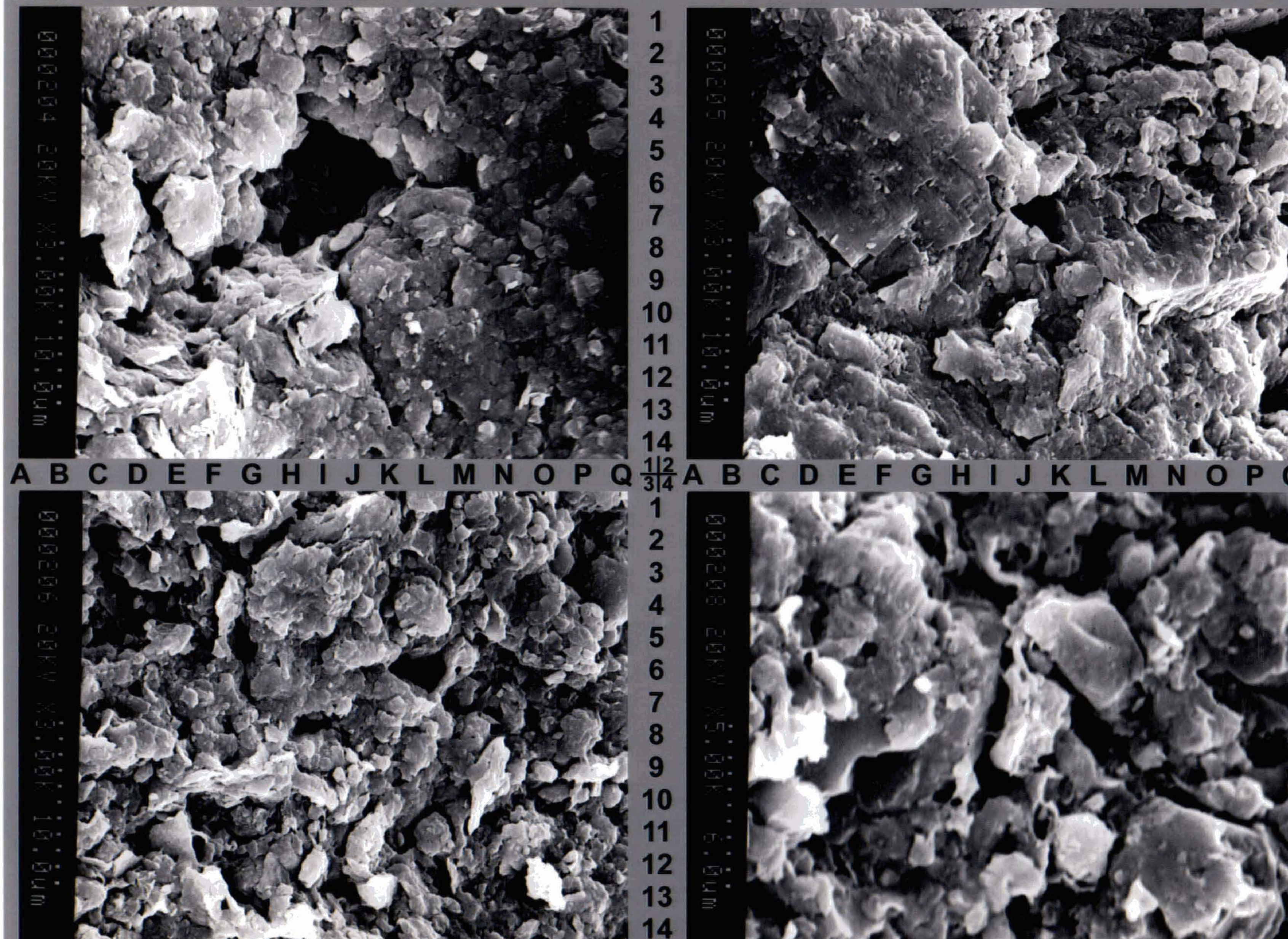

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PLATE #9
SAMPLE #11: 1670.00-1675.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 10
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

ARGILLACEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A **Permeability**: N/A

Sample #14: 1685 - 1690m

1 Low magnification view of a micro- to medium crystalline mudstone to wackestone that only contains moderate amounts of bioclasts. Some of the micrite is rich in argillaceous material (darl brown chips G9). The bioclasts in this carbonate are echinoid spicules, sponge spicules, local coral, plus trace bryozoa and pelecypod shell fragments. These grains are floating calcareous micrite that is often clay-rich. No visible porosity was detected in this thin section but micro-intercrystalline was seen in SEM. **x12.5 ppl**

2 Moderate magnification view of wackestone with recrystallized micrite supporting a fabric of small pelecypod shell debris (G5) and possible echinoid spicules (K5). Non-ferroan (pink G4) and ferroan calcite (blue G9) act as minor fine crystalline cements. **x50ppl**

3-4 Higher magnification views showing siliceous sponge spicules (3:P7). Chert replaced indistinct bioclasts (3:J7) and calcareous bioclastic debris (3:N1) float in clay-rich calcareous micrite matrix. Photo 4 shows anhedral ferroan dolomite (4:B7) and ferroan calcite (K8) floating in the fabric of this wackestone. **x100ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

CANADIAN FOREST OIL LTD. JANUARY, 2003
AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45 A10002
AGE: MISSISSIPPIAN

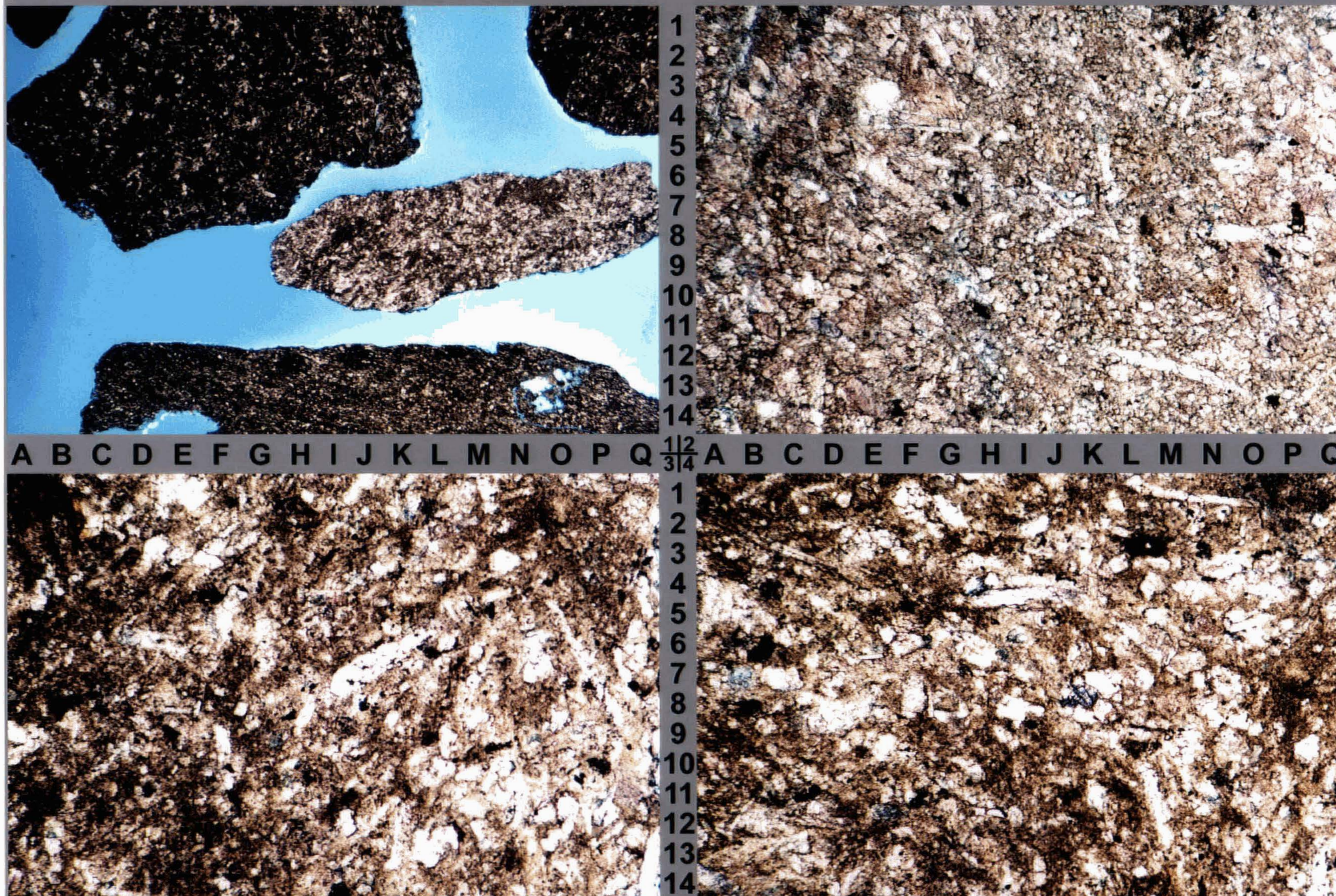

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PLATE #10
SAMPLE #14: 1685-1690m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 11
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

ARGILLACEOUS LIMESTONE (MUDSTONE TO WACKESTONE)

Porosity: N/A

Permeability: N/A

Sample #14, 1685 - 1690m

1 - 4 A series of very high magnification views of siliceous limestone with a typical EDX reading (relative counts per 20 sec) as follows: Ca 1835, Si 499, Al 100, Fe 69, K 28 and Mg 26. The higher aluminum, potassium and possibly magnesium readings in EDX suggest more clay-rich minerals intermixed with the micrite. Trace possible smectite (2:J4) clay occur lining a few pores. Note that the moderate volume of micro-intercrystalline pores (1:K9, 2:I12, 3:L11. 4:M5) that appear to be poorly to moderately interconnected. These micro-intercrystalline pores have pore size of 3μm (1:J4), 4.5μm (2:J6), 2μm (3:L11) and 1μm (2:N12). Detrital clays are intermixed with this carbonate and consist of illite (3:K6), kaolinite (2:G13) and previously mentioned smectite. Photo 4 is a closer view of silica-rich chip with good intercrystalline porosity. Possible minute sponge spicules (4:H4) were observed in a micro-quartz crystal. The actual matrix permeability is low due to the very small pore size. **x3000, x3000, x5000, x5000**

1	2
3	4

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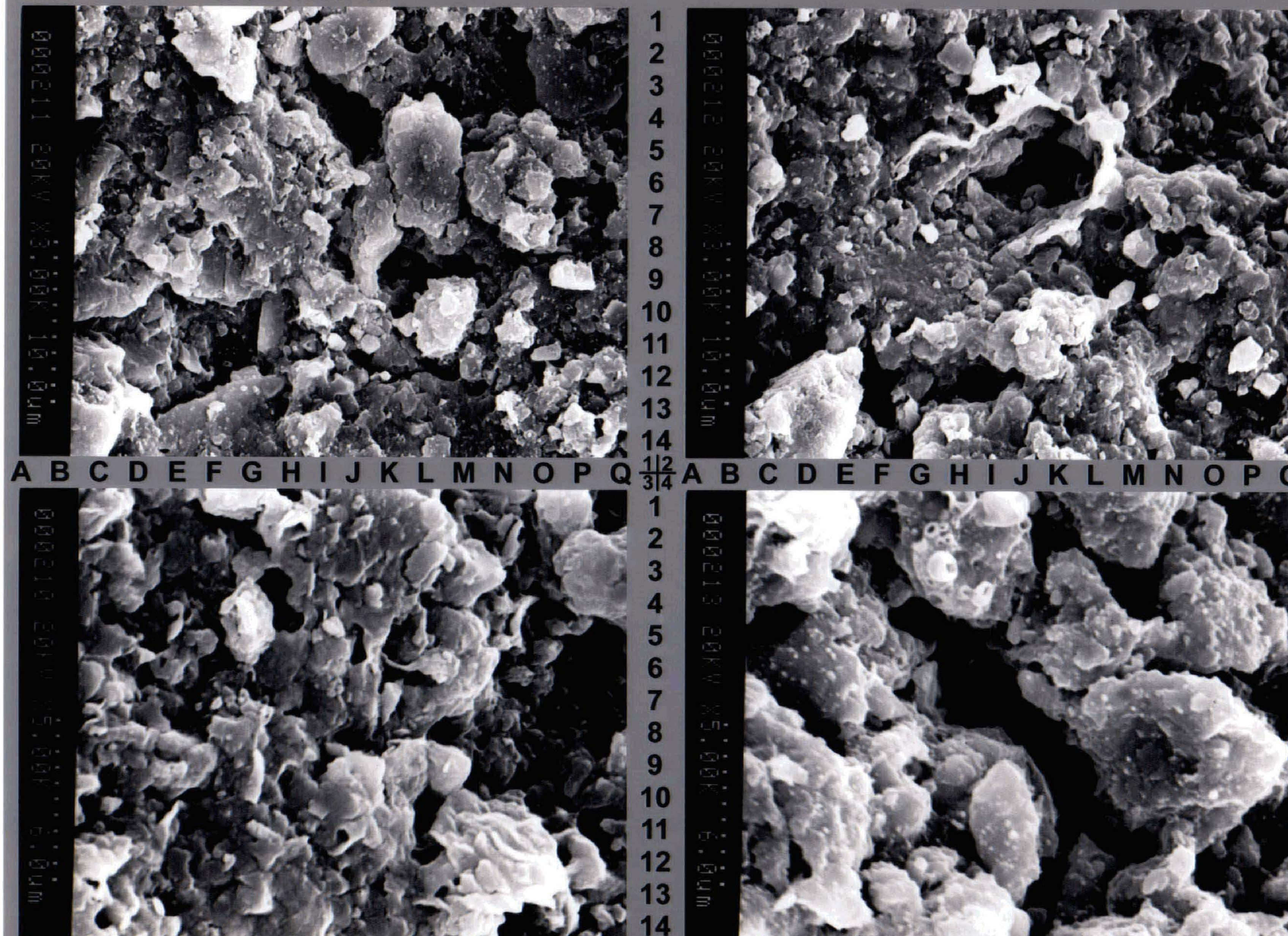

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PLATE #11
SAMPLE #14: 1685.00-1690.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 12
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A **Permeability**: N/A

Sample #17: 1700 - 1705m

1 - 2 Moderate magnification views of chips with highly broken-up siliceous sponge spicules (1:K13, 2:G9) floating in calcareous micrite matrix (pink 1:J8, 2:I11). These siliceous sponge spicules are partially recrystallized to chert. The other bioclasts are echinoid spicules, bryozoa and pelecypod shell fragments. Very thin bitumen healed micro-fractures (1:A5 to J10) bisect the chip in photo 1. Anhedral poorly formed dolomite rhombs (D11) and trace micropyrite (black M12) replace micrite in the fabric of photo 2. Overall this sample is micro- to very coarse crystalline bioclastic mudstone to packstone that is partially replaced by silica (forming chert) and dolomite (non-ferroan).. These grains are cemented locally by calcite spar. No visible porosity was observed, but micro-crystalline porosity is seen in the SEM. **x50 ppl x50ppl**

3 - 4 High magnification views of cherty limestone. Anhedral calcite pseudospar (pink) and chert (light brown 3:H7, 4:E6) replace the original matrix in these views. This chert appears to be microporous and stained with bitumen. The calcite pseudopar has replaced matrix material and framework biolasts. Note the indistinct fossil ghosts after echinoid spicules (4:L8) and possible shell fragments (4:K13). Scattered siliceous sponge spicules (white 3:J-K6) float in fabric of this carboonate. **x100ppl x100ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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JANUARY, 2003
A10002

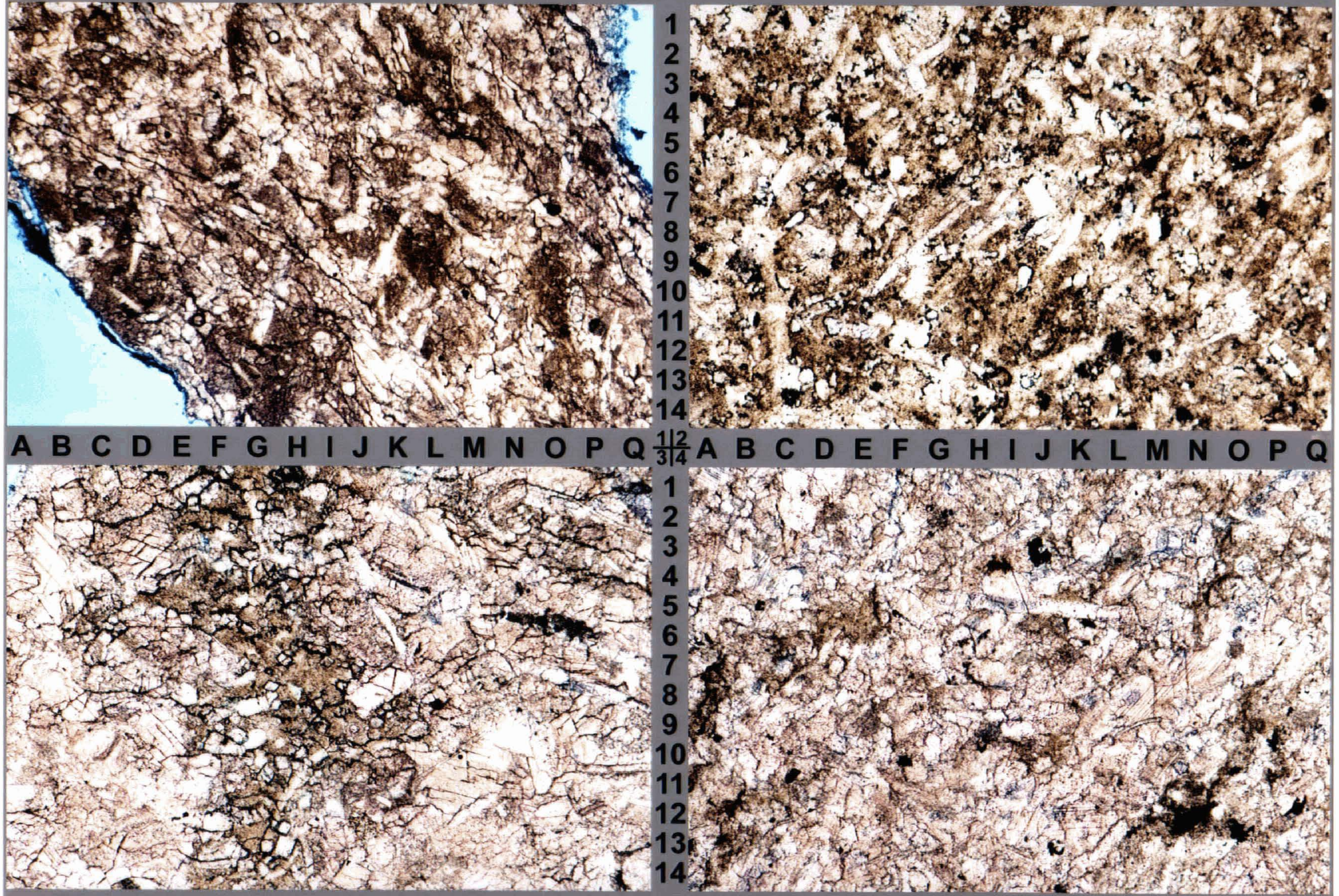

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PLATE #12
SAMPLE #17: 1700-1705m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 13
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A **Permeability**: N/A

Sample #17, 1700 - 1705m

1 - 4 A series of very high magnification views of silicified carbonate (chert) with good micro-intercrystalline porosity partially occluded by crystal coating bitumen (1:H12, 2:J5, 4:O9). This chert probably occurs as patches in calcite pseudospar as seen in Plates 12.3 and 12.4. Note that the micro-intercrystalline pores still appear to be well interconnected even with this precipitated bitumen. These micro-intercrystalline pores have pore size of 7µm (1:N8), 5µm (2:I7), 1.2µm (3:I7) and 2µm (1:E2). Photo 3 shows a pyrite framboid (I9), wispy illite/smectite ribbons (L11) and pitted quartz crystals (3:I3). The typical EDX reading (relative counts per 20 sec) as follows: Ca 493, Si 566, Al 126, Fe 56, K 30, Ba 64, S 39 and Mg 20. The presence of calcium suggest relatively high amounts of calcite intermixed or close to this chert. **x3000, x3000, x3000, x5000**

1	**2**
3	**4**

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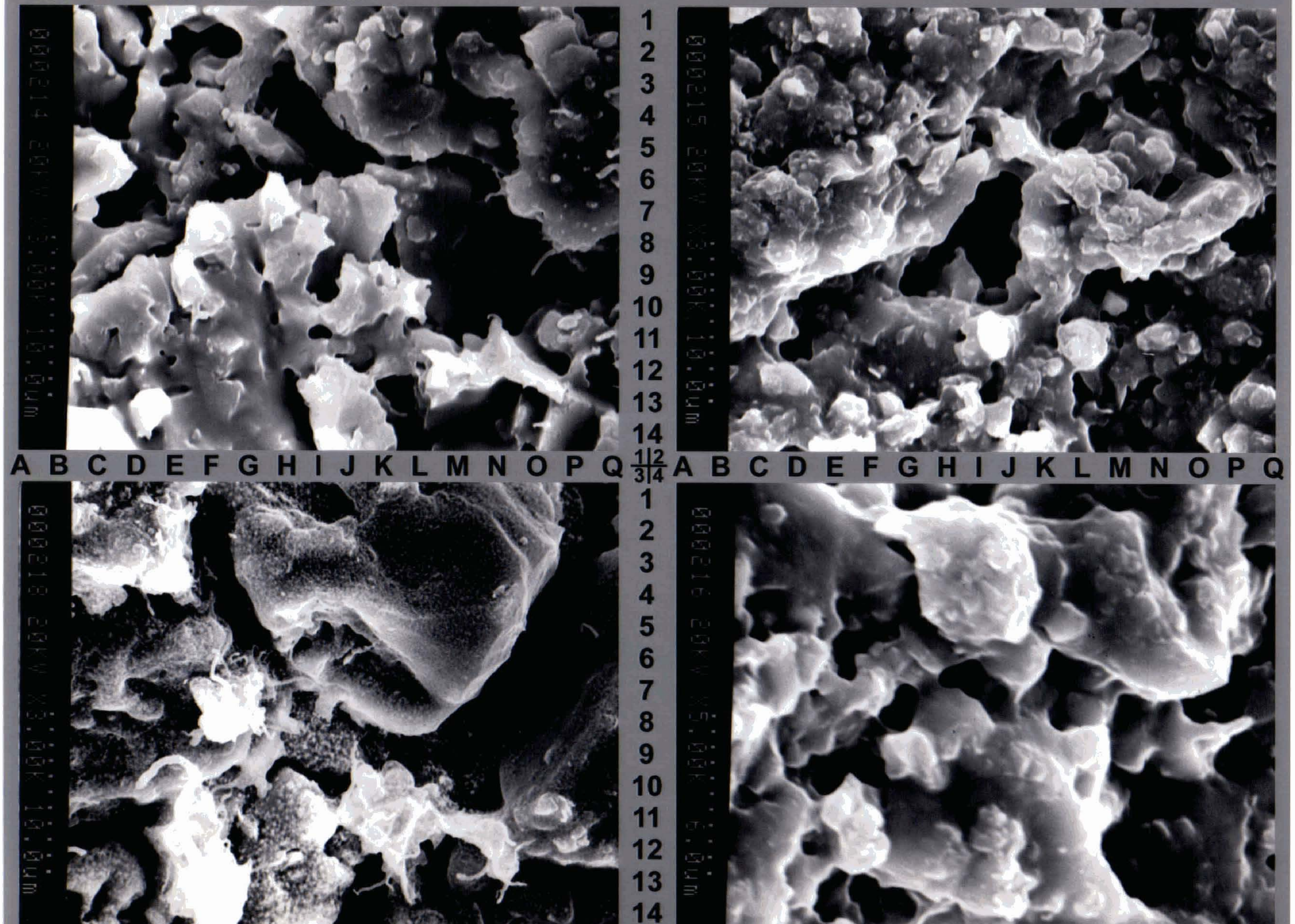

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PLATE #13
SAMPLE #17: 1700.00-1705.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 14
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (WACKESTONE TO PACKSTONE)

Porosity: N/A **Permeability: N/A**

Sample #19: 1745 - 1750m

1 Moderate magnification view of a micro- to coarse crystalline bioclastic wackestone to packstone that is partially replaced by silica (forming chert K12) and dolomite. Trace pyrite framboids locally replace calcite. The bioclasts in this carbonate are echinoid plates, ossicles and spicules, plus coral, brachiopod and possible ostracod shell fragments. These grains are cemented locally by calcite spar, ferroan calcite and dolomite (mostly ferroan). No visible porosity was detected in this thin section but micro-intercrystalline was seen in SEM. The thick chert band in this view (E4 to L13) is parallel to bedding and is a replaced bioclast and not a fracture. **x50 ppl**

2 Moderate magnification view of a packstone consisting of coral totally cemented by calcite spar cement (L3). Note the very fine crystalline bioclasts debris (D4) in the micrite matrix. **x50ppl**

3 Higher magnification view a highly silicified (chert - white) carbonate. This chert has replaced both micrite and bioclasts (C5). Remnant micrite (N5) and subhedral ferroan calcite (blue-pink I9) float in fabric of this chip. **x100ppl**

4 Higher magnification view of bioclast rich chip that highly replaced by chert (C12), euhedral ferroan calcite (pink-blue F8) and dolomite (N11). Ferroan dolomite appears to postdate silicification of this dolomite. Bitumen precipitation is the last diagenetic event in this sample. **x100ppl**

1	2
3	4

2 mm **x12.5** | **500 µm** **x50** | **250 µm** **x100** | **125 µm** **x200**

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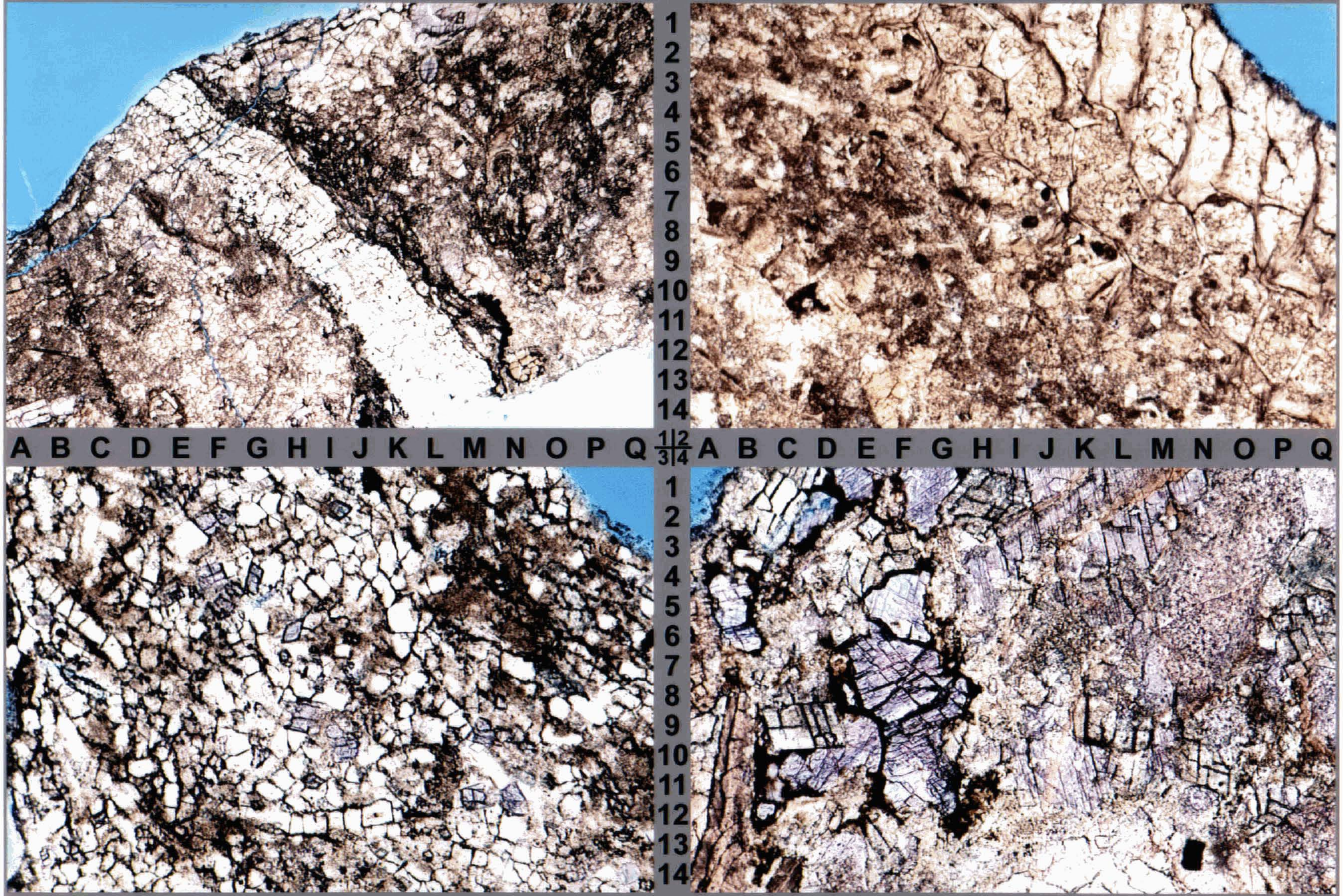

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PLATE #14
SAMPLE #19: 1745-1750m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 15
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS LIMESTONE (MUDSTONE TO PACKSTONE)

Porosity: N/A | **Permeability**: N/A

Sample #19, 1745 - 1750m

1 - 4 A series of very high magnification views of partially silicified limestone with moderate micro-intercrystalline porosity (1:G7. 2:H10, 3:H13). The typical EDX reading (relative counts per 20 seconds) is as follows: Ca 3890, Si 1172, Fe 87, Al 245, K 252, Cl 560 and Ba 89. Chlorine and most of potassium detected probably represent potassium chlorite solution used in cleaning this sample. The barium may be from drilling mud. The microporous section of this sample appears to be a mixture of micrite and fine crystalline chert (1:D8). These micro-intercrystalline pores have pore size of 6µm (1:G7), 7µm (2:K6I7), 2.5µm (3:K6) and 1.5µm (2:I10). Due to these pore sizes permeability is probably low. Photo 4 shows illite ribbons (H4, I8) coating a large sparry calcite crystal. **x300/x3000, x3000, x3000, x5000**

1	**2**
3	**4**

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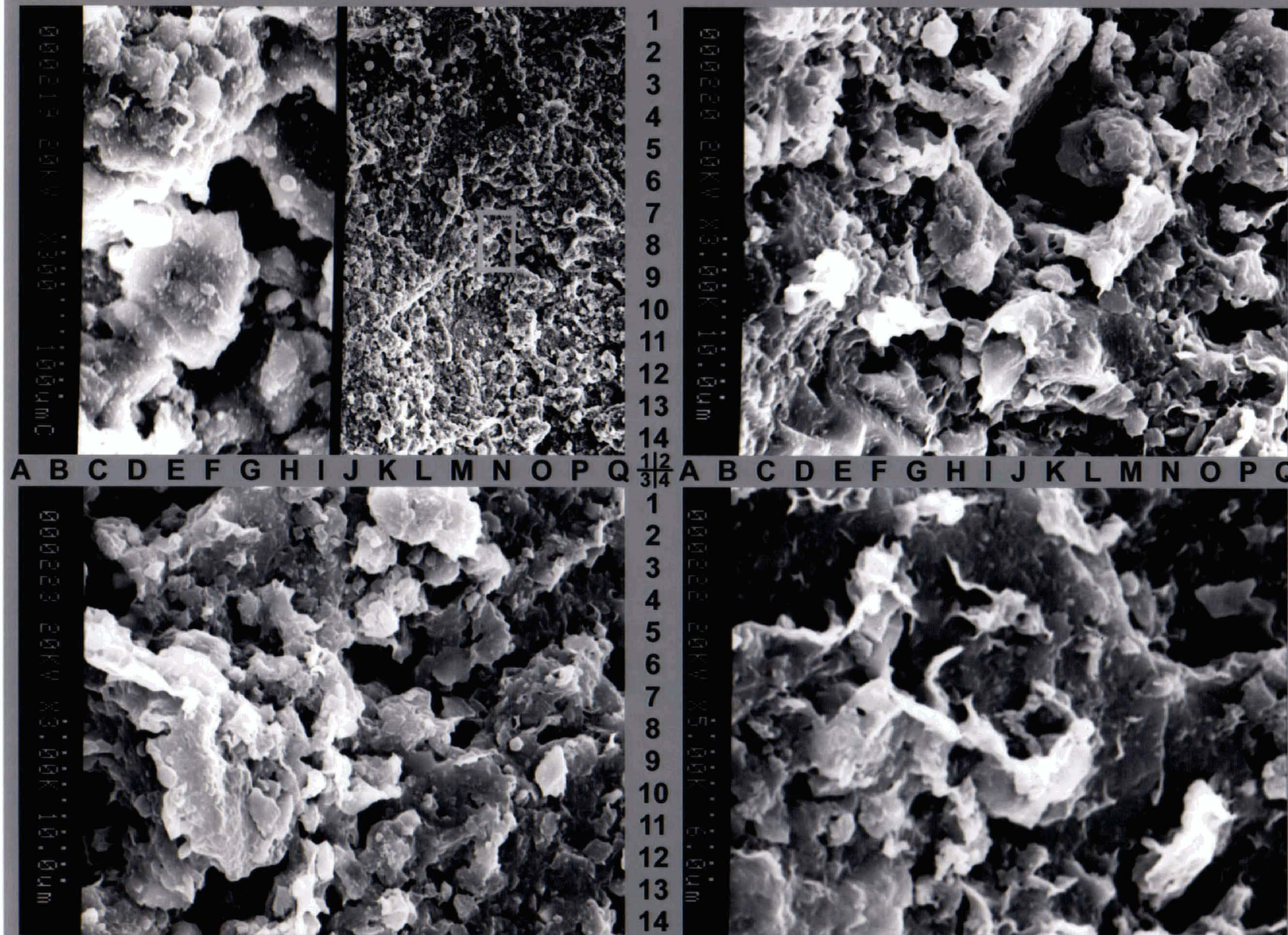

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PLATE #15
SAMPLE #19: 1745.00-1750.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 16
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

CALCAREOUS SHALE

Porosity: N/A **Permeability: N/A**

Sample #23: 2340 - 2345m

1 Low magnification view of a calcareous shale (black) that contains minor amounts dolomite and organic debris. Bioclasts occur in minor amounts and consists of well broken up pelecypod or brachiopod shell fragments, bryozoa, foraminifera and recrystallized calco-spheres. Only trace quantities of chert was detected in this thin section but the SEM from this same depth has pure chert chips (Plate 17). Rare pseudospar (I14) and micrite limestone chips occur in this sample. A large ferroan calcite chip (blue H9) has parallel striations, which suggests possible fracture cement fill. No visible porosity was detected in this thin section. Micro-intercrystalline porosity was abundant in the chert found in SEM. **x12.5 ppl**

2 - 4 Moderate magnification view of calcareous shale consisting predominately of clay rich matrix (brown) that is calcareous. Very fine crystalline bioclasts in these views consists of pelecypod to brachiopods shell fragments (2:D9, 3:N11), echinoid spicules (2:L8) and ferroan calcite or ferrroan dolomite replaced calco-spheres (light blue 3:N12) or foraminifera (light blue 4:I7). Rare pyrite cemented bioclasts (3:D4) were also detected. The dark brown zones in this shale are rich in organic material (2:O10, 3:P5, 4:P5). **x50ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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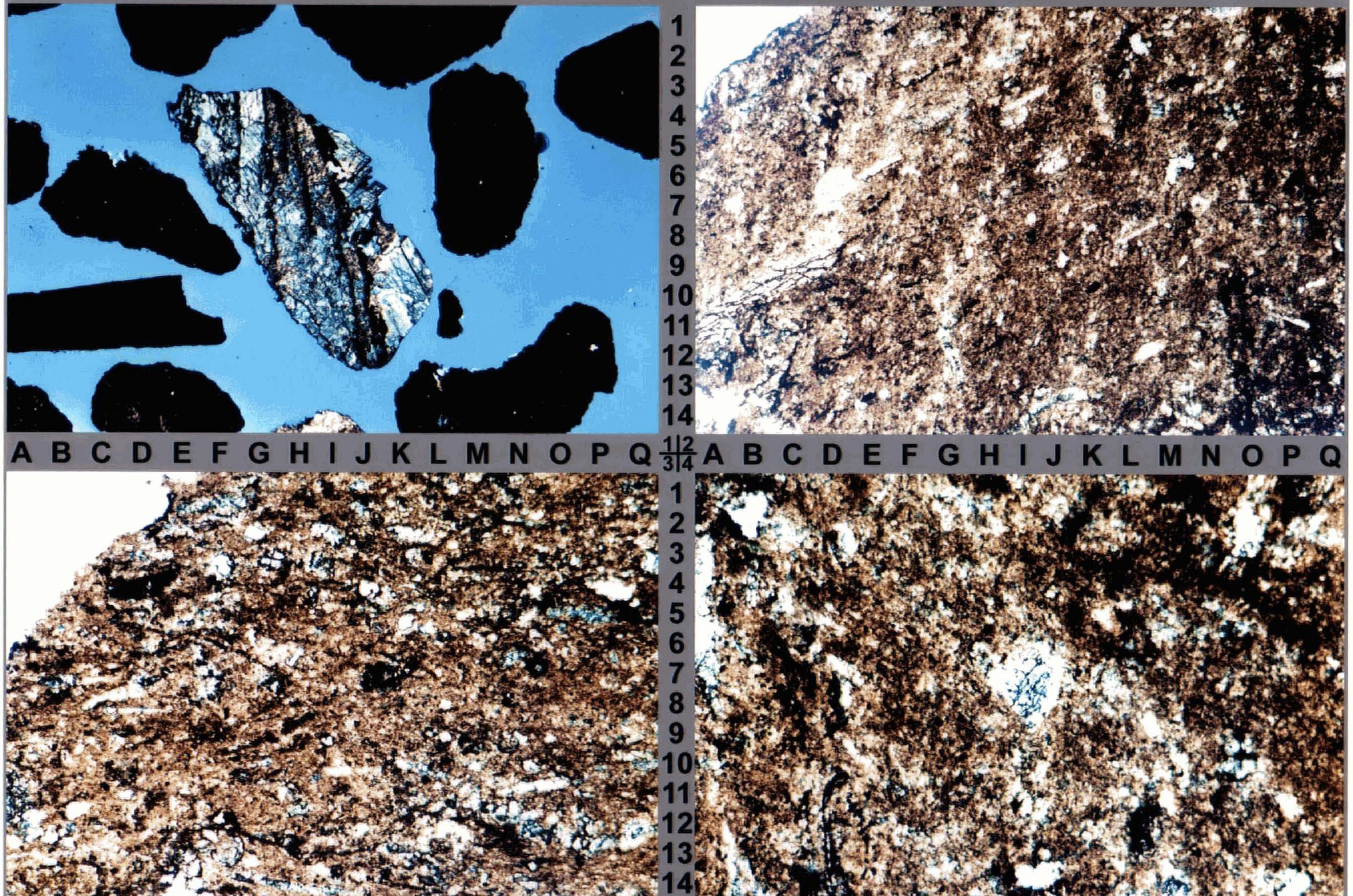

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PLATE #16
SAMPLE #23: 2340-2345m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 17
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

CHERT TO SILICEOUS SHALE

Porosity: N/A **Permeability: N/A**

Sample #23, 2340 - 2345m

1 - 4 A series of very high magnification views of silicified shale/limestone with moderate to well interconnected micro-intercrystalline (1:D3. 2:G7, 4:G4) or possible biomoldic (3:N12) porosity. The typical EDX reading (relative counts per 20 seconds) is as follows: Ca 146, Si 1407, Fe 260, Al 275, K 113, Cl 82, Ba 37 and Mg 22. Chlorine and potassium detected probably represent the potassium chlorite solution used in cleaning this sample. The barium may be from drilling mud. The micro-intercrystalline pores have pore sizes of 5µm (1:I9), 3.5µm (2:G7), 7µm (2:H4, 4:G4) and 1µm (2:C10). The biomoldic pore diameters are approximately 7µm. Note the elongated euhedral quartz crystals (3:I10, 4:L5) that may originate form on sponge spicules. The subhedral to euhedral quartz crystals bounding these pores (1:I10, 3:I5, 4:N9) result in a clean homogeneous porosity. Due to these pore size and cleanness of the porosity, permeability is higher than previously described samples. Trace quantities of illite/smectite (3:O9, 4:P7) and kaolinite (2:H8) were detected in this chert. **x3000, x3000, x3000, x5000**

1	2
3	4

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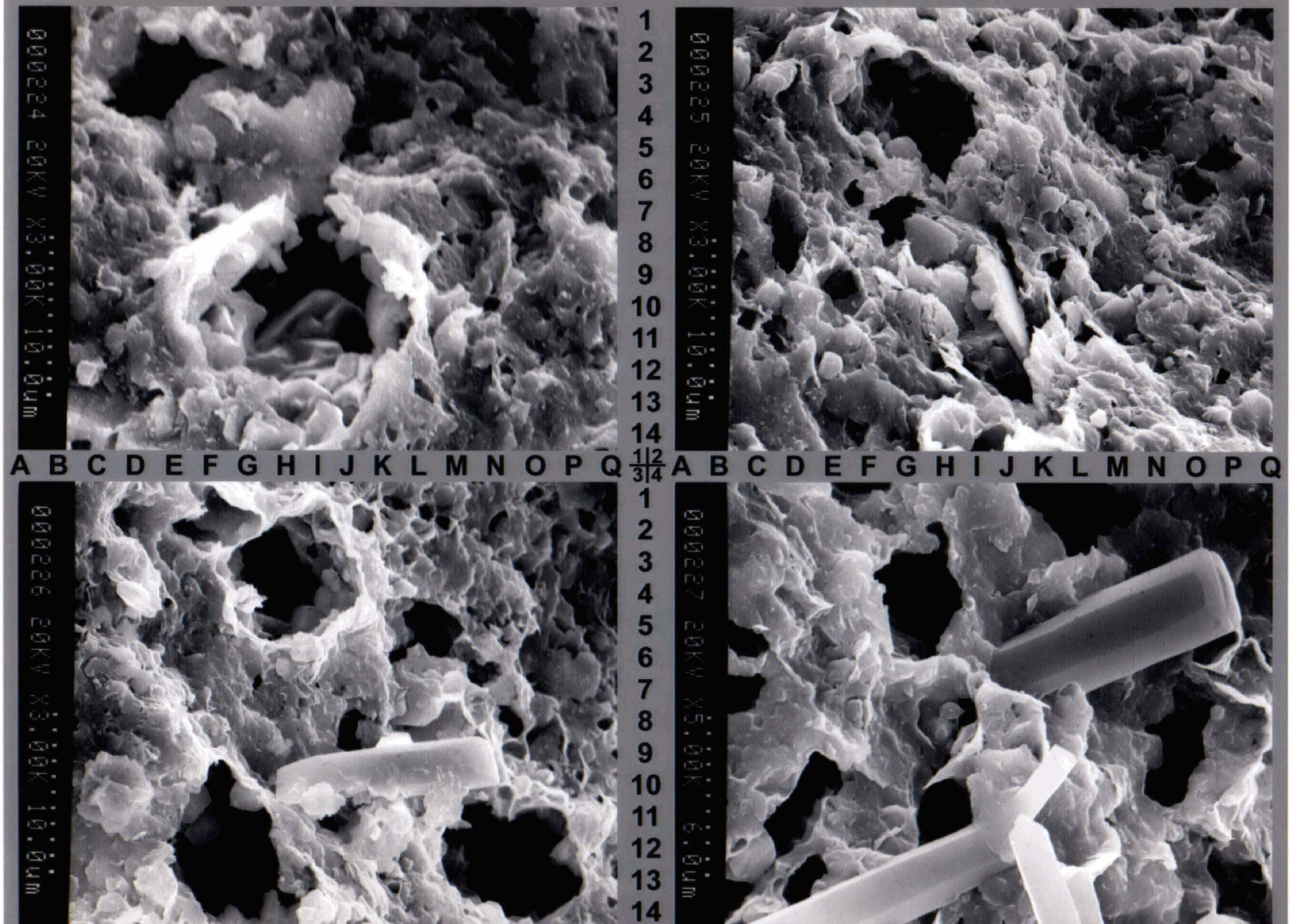

PLATE #17

SAMPLE #23: 2340.00-2345.00m

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SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 18
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS AND CALCAREOUS SHALE

Porosity: N/A

Permeability: N/A

Sample #24, 2370 - 2375m

1 - 4 A series of very high magnification views of silicified shale/limestone with poor to moderately interconnected micro-intercrystalline (1:M8. 2:K4, 3:K6, 4:J8) porosity. The typical EDX reading (relative counts per 20 seconds) is as follows: Ca 748, Si 921, Fe 78, Al 239, K 327 and Cl 196. Chlorine and small portion of the potassium detected probably represent potassium chlorite solution used in cleaning this sample. Photo 1 shows remnant illite and kaolinite (N7) floating in tight diagenetic quartz (chert) and calcite. In Photos 2 to 4 the pore system better with pore diameters of 6μm (2:H10), 3μm (2:K6), 4μm (4:E9) and 2μm (J8). Remnant kaolinite booklets (2:L-M9, 3:F10, 4:O6) and illite ribbons (3:L6, K11) are intermixed with micrite and chert. Due to small quantity pores and more isolated porosity suggest poor interconnection and poor permeability. **x3000, x3000, x5000, x5000**

1	**2**
3	**4**

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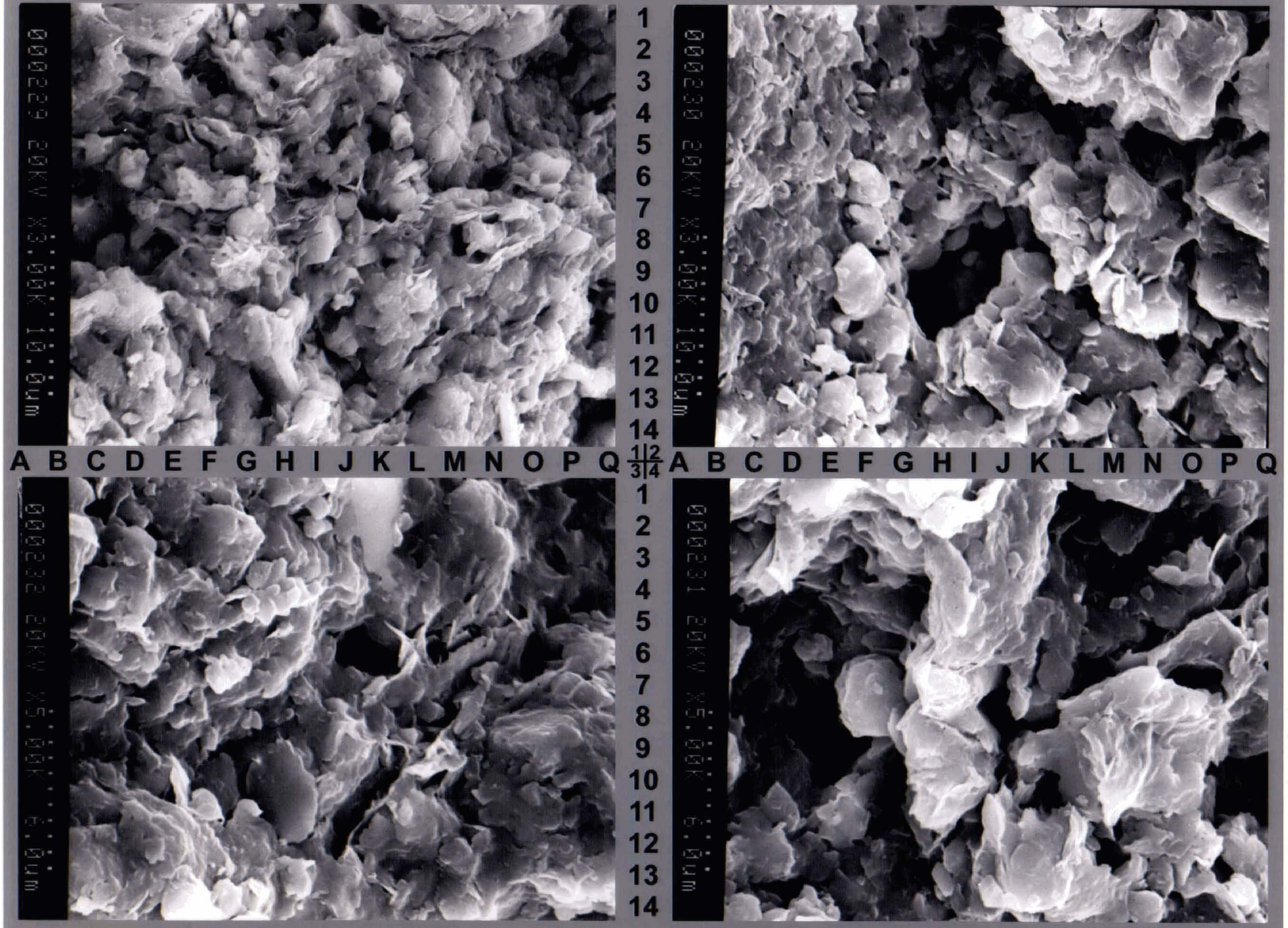

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PLATE #18
SAMPLE #24: 2370.00-2375.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 19
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

SHALE

Porosity: N/A | **Permeability**: N/A

Sample #25: 2375 - 2380m

1 Low magnification view of organic shale (black) that contains diagenitic ferroan calcite, dolomite (mostly non-ferroan) and chert. Bioclasts occur in minor amounts (locally common) and consists of bryozoa (N4), plus well broken up pelecypod or brachiopod shell fragments, echinoid spicules or plates, foraminifera, possible ostracod shells and recrystallized calco-spheres. Minor amounts of quartz silt are detected in this shale. No visible porosity was detected in this thin section. Micro-intercrystalline porosity probably occurs in the siliceous shale and diagenetic chert similat to samples 23 and 24. **x12.5 ppl**

2 - 4 Photo 2 is a moderate magnification view of bryozoa fragments with intrafossil pores occluded by bituminous chert (light brown H11) and ferroan calcite (blue M11). Photos 3 and 4 show disseminated ferroan calcite (blue 4:G9) and dolomite crystals floating in organic-rich (black 4:I8) matrix clays (dark brown). Some of this carbonate appears to recrystallized bioclasts (echinoid ossicles [4:K6] or spicules [3:K6] and calco-spherules [4:D12]). The organic content in this shale is evenly distributed through out the clays and silt of this shale. **x50ppl x100ppl x100ppl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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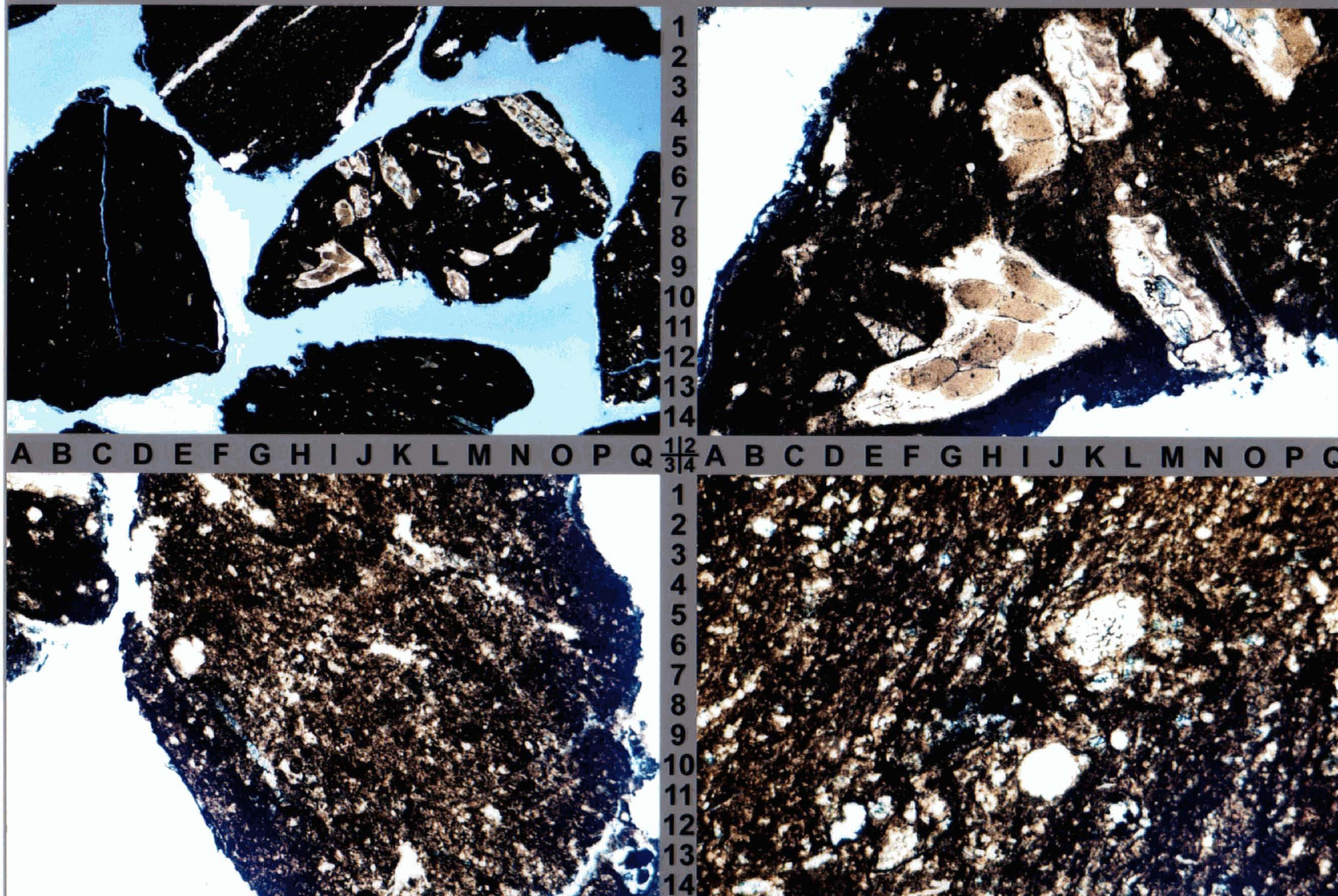

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PLATE #19
SAMPLE #25: 2375-2380m

SEM PHOTOMICROGRAPH DESCRIPTION: PLATE 20
LOCATION: AMOCO S. POINTED MOUNTAIN (D-10) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILICEOUS AND CALCAREOUS SHALE

Porosity: N/A **Permeability: N/A**

Sample #29, 2880 - 2885m

1 - 4 A series of very high magnification views of silicified shale/limestone with moderately interconnected micro-intercrystalline (1:N2, 2:M11, 3:N7, 4:N8) porosity. A few of the larger pores (1:M8) may be leached bioclasts (calco-spheres). The typical EDX reading (relative counts per 20 seconds) is as follows: Ca 122 - 264, Si 486 - 516, Fe 81 - 109, Al 116 – 150, K 115, Cl 85 – 165, Mg 18 – 26 and Ti 31. Chlorine and a portion of the potassium detected probably represent potassium chlorite solution used in cleaning the sample. Non altered clay minerals (2:G8, 3:M11) are most abundant in photos 2 and 3. The clay minerals are abraded koalinite booklets and illite ribbons (3:M11). The quartz subcrystals have anhedral to subhedral (3:L5, H1) crystal habit. The pore system has diameters of 2μm (1:G8, 3:F11), 4.5μm (2:M11) and 5μm (4:G9). These pore diameters are smaller and more heterogeneously distributed than the pure chert observed in sample 23. Due to small pore size the matrix rock in these chips have poor permeability. **x3000, x3000, x3000, x5000**

1	2
3	4

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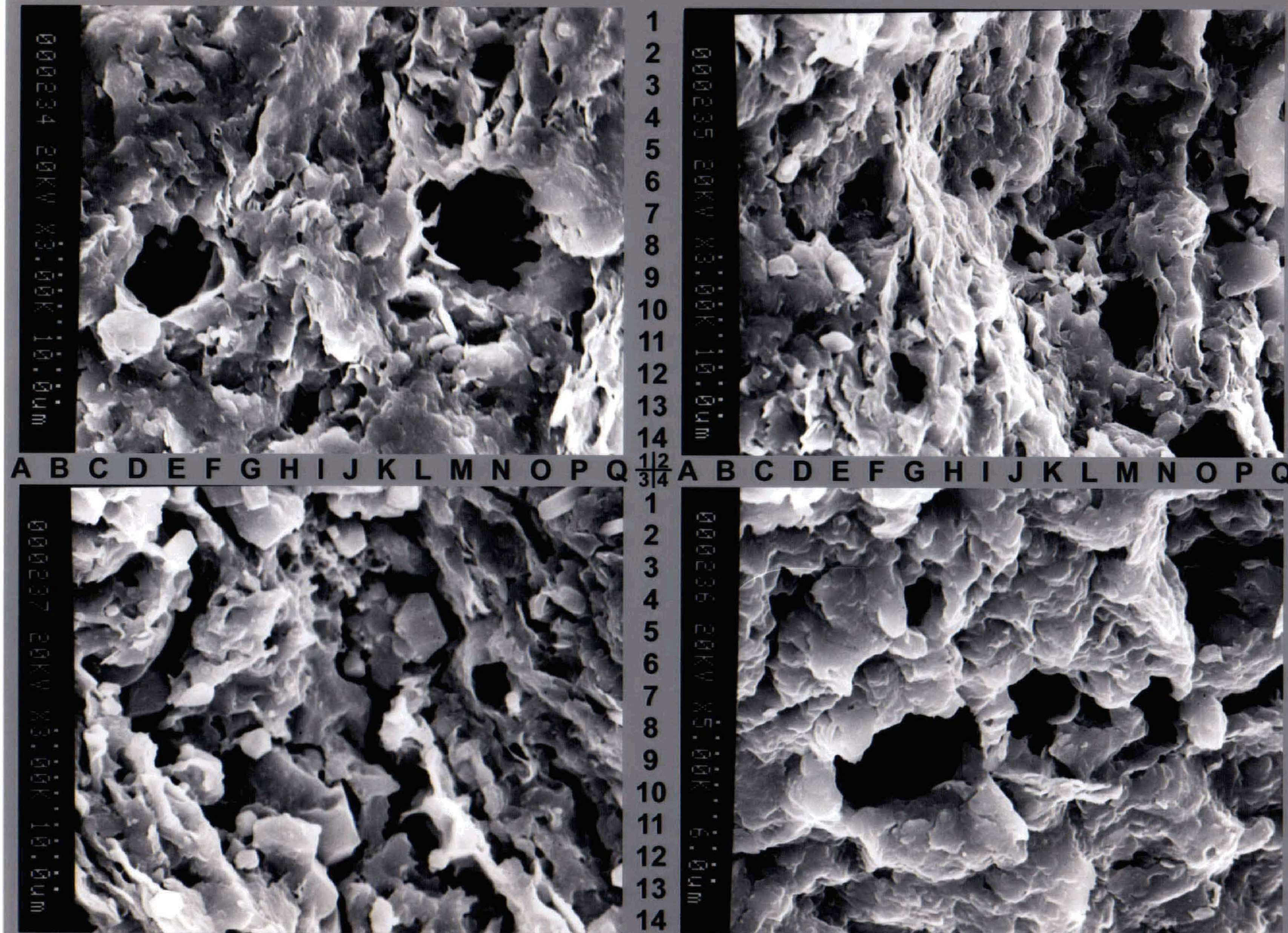

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PLATE #20
SAMPLE #29: 2880.00-2885.00m

THIN SECTION PHOTOMICROGRAPH DESCRIPTION: PLATE 21
LOCATION: AMOCO S. POINTED MOUNTAIN (D-1) L-68-60-20-123-45
MISSISSIPPIAN AGE

SILTY TO SILICEOUS SHALE

Porosity: N/A **Permeability**: N/A

Sample #30: 2885 - 2890m

1 Low magnification view of a silty (brown G13) to organic-rich shale (black O8) that are locally bisected by chert healed fractures (O5). A few of the chips have parallel carbonaceous laminae (G5). Minor ferroan to non-ferroan dolomite rhombs float in the fabric of the silty shale. Only trace bioclasts where observed in this shale and they include calco-spheres, ostracod and pelecypod shell fragments. No visible porosity was detected in this thin section. **x12.5 ppl**

2 High magnification view of ferroan dolomite rhombs (turquoise M6) floating in a silty shale. This coarse to medium sized silt consists mostly of quartz. This silty shale is generally not silicified. **x100ppl**

3-4 Moderate magnification view in plane and cross polarized light illustrating large polycrystalline to chert healed fractures (3-4: J4, P4). If these fractures are partially open elsewhere they could act as permeability channels. **x50ppl x50cpl**

1	2
3	4

2 mm	500 μm	250 μm	125 μm
x12.5	x50	x100	x200

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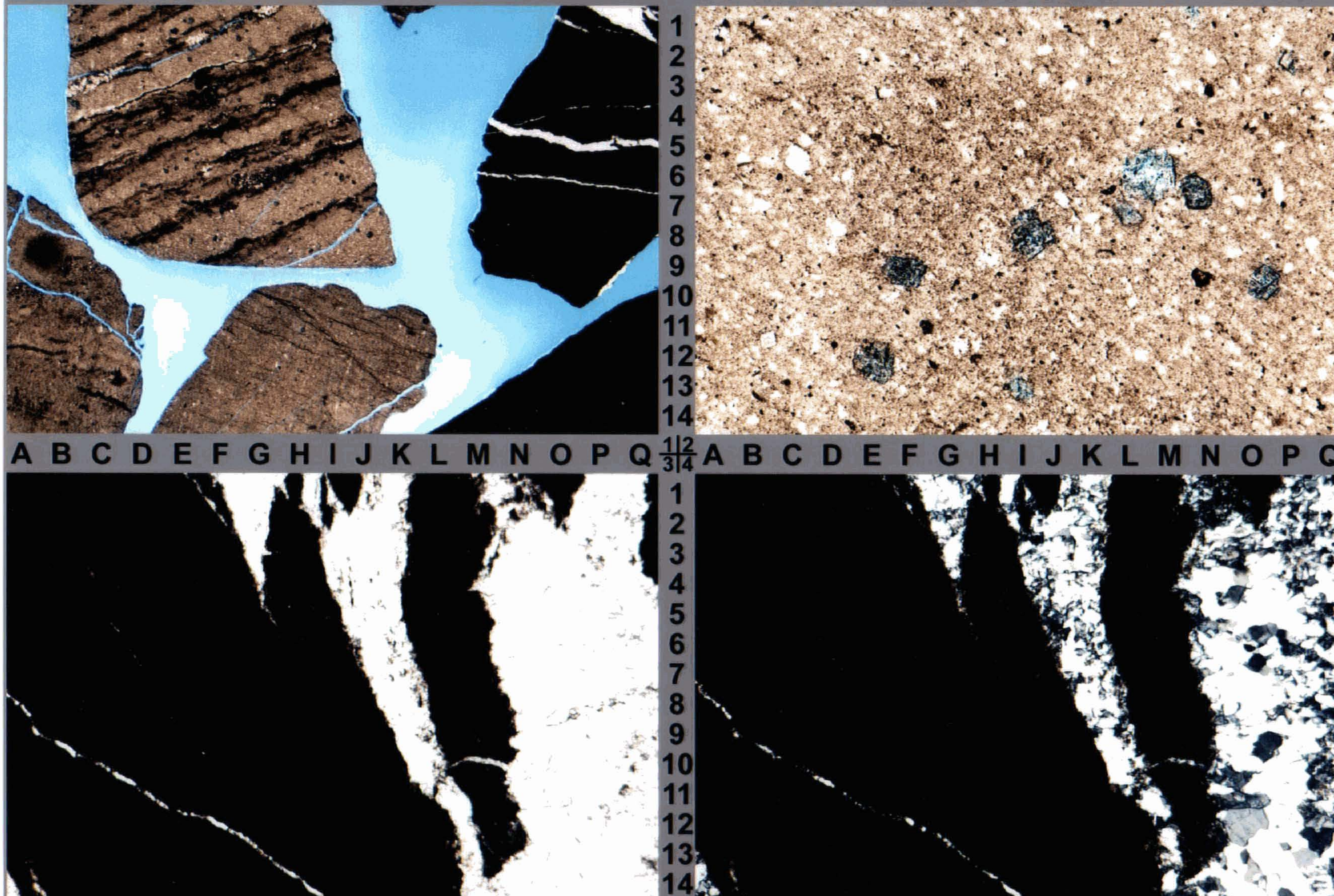

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PLATE #21
SAMPLE #30: 2885-2890m

PROFESSIONAL GEOLOGIST
Philip Haig
ALBERTA

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Date Feb 3 2007
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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Philip Haig

Prepared by Klaus Heizmann, M.Sc. (Geol.)