APPENDIX H
LABORATORY REPORTS

Strength Testing Reports
Corrosion Testing Reports
Atterberg Limits Testing Reports
Petrographic Analysis Reports

Strength and Direct Shear Testing Results

GeoTest Unlimited

Geo Test Unlimited (GTU)

Test Equipment Design & Fabrication
Laboratory & Field Testing
Consulting Services

Dr. Anders Bro

October 29, 2006

Rock Testing
WDOT - I90 Hyak Extension

Wyllie & Norrish Rock Engineers
17918 NE 27th St.
Redmond, WA 98052

Dear Norm,

This letter report summarizes the unconfined compression, point load, and direct shear tests performed on the samples that you had sent to my lab a number of weeks ago. The report summarizes the test results along with some comments about the testing program that you might find helpful in interpreting the results. The standard test procedures used for these tests are appended to this letter, along with a compact disk containing the data files and photographs of the pre-and post-test samples.

Of the 39 samples sent to me, seven were slated for unconfined compression tests along with axial and diametral point load tests. (Of the samples slated for point load testing, there was an insufficient length of Sample 105 from Boring H-109-06 to perform a diametral point load test.) In addition, three filled interfaces were slated for direct shear testing. The remaining samples were not tested.

Unconfined Compression and Point Load Testing

The unconfined samples were for the most quite competent. In the sample descriptions that accompanied the samples, all of the samples (with the exception of Samples 103A&B from Boring H-201-06) were described as “Meta-Welded Lapilli Tuff”. Although I am not a geologist and have but little practice in rock identification, there seemed to be five varieties of extrusive volcanic rock in this set of samples, rather than one rock type.

Sample 101A&B from Boring H-101-06 consisted of a light gray light weak volcanic ash. This rock appeared to be quite altered as it contained large pockets of dirty white clay, likely the result of alteration of large mineral clasts.

Sample 105 from Boring H-109-06 was also distinctly different from the other samples in that it was brown and included numerous well-healed shears. This is clearly a rock that has been altered and not in a class with the other rocks.

Samples 103A&B from Boring H-201-06 is also distinctly different from the other rocks in that it had a finer-grained texture and contained numerous fine calcite inclusions. Although the rock is more dense than the other rocks, I am not sure that it is a basalt. The softness of the rock (as expressed by the dull sound during saw cutting and grinding) is not so indicative of basalt. I have called it a tuff, but I have my doubts about this classification as well.

Lastly Sample 102A&B from Boring H-203-06 was very different from the other samples in that it was a reddish purple and consisted of a fine grained, relatively soft rock. This rock was also different from the others in that it had a quite low modulus and incurred quite large strains to failure. It may be a tuff, but of a completely different nature than the other samples in that it is very ductile and quite porous. When this rock was moistened, the moisture was immediately wicked into the rock, unlike all the other rocks for which the water remained on the rock surface.

I expect that these differing rock types are typical of a volcanic deposit and a result of the different episodes of volcanic deposition, as opposed to representing a thick uniform volcanic deposit. The heat of some of these deposits during deposition may have resulted in a low grade metamorphism that resulted in the highest strength rocks (with exceptionally high strengths - above 27,000 psi) and correspondingly the higher densities. I expect that the lower strength rocks represent those deposits that were not metamorphosed.

The test results are tabulated as follows:

Unconfined Compressive Strength and Point Load Test Results

Boring/ Sample #	Depth (ft.)	Description	Density (pcf)	Brazilian Splitting (psi)	UC Strength (psi)
H-101-06 #101A	94.0-94.7	Light gray altered tuff with large white clay inclusions.	157.8		4896
H-101-06 #101B	94.7-95.4	Light gray altered tuff with white clay inclusions.		165[d] 140[a]	
H-103-06 #101A	34.2-34.9	Medium gray fine to medium grained tuff with no apparent planes of weakness.	163.9	982[a]	29,878
H-103-06 #101B	34.9-35.7	Medium gray fine to medium grained tuff with no apparent planes of weakness.		1267[d]	
H-107-06 #101A	30.0-30.6	Medium gray fine to medium grained tuff with a diagonal healed fracture.		1183[d] 503[aw]	
H-107-06 #101B	30.6-31.2	Medium gray fine to medium grained tuff with a few tight axial non-through-going fractures.	164.1		27,373
H-109-06 #105	128.9-129.8	Medium brown slightly altered tuff with several brown healed shears.	161.3	168 [awi]	6287
H-110-06 #102A	80.1-80.6	Medium gray fine to medium grained tuff with no apparent planes of weakness.	164.0		27,724
H-110-06 #102B	80.6-81.3	Medium gray fine to medium grained tuff with no apparent planes of weakness.		1222[d] 1260[a]	
H-201-06 #103A	76.9-77.6	Greenish medium gray fine grained tuff (?) with numerous fine calcite inclusions.		541[d]	
H-201-06 #103B	77.9-78.7	Greenish medium gray fine grained tuff (?) with numerous fine calcite inclusions.	167.6	676[a]	13,626

Unconfined Compressive Strength and Point Load Test Results (cont.)

H-203-06 #102A	44.3-45.0	Reddish purple fine grained tuff (?) with numerous white mineral inclusions.	155.3	343[ai]	12,702
H-203-06 #102B	45.3-46.1	Reddish purple fine grained tuff (?) with numerous white mineral inclusions.		408[d]	

Notes: a. Axial Point Loading
d. Diametral Point Loading
w. Failed along a plane of weakness
i. Invalid – failure did not pass through both points of loading.

Direct Shear Testing

Of the direct shear tests slated for testing, only one, Sample 103 Boring H107-06, was received in a relatively undisturbed condition. The other two, 105 from Boring H-106-06 and 102 from Boring H-108-06, were badly damaged in shipping and could not be tested. Ultimately, Sample 103 was used for a total of three direct shear tests. The 3/8 inch filled planar joint was steeply dipping joint and so could be cut in half to create two testable samples. The sample halves were designated as 103A and 103B. The third direct shear tests consisted of a saw-cut and ground interface of the rock from Sample 103 just adjacent to the filled joint. This sample was designated as 103SC.

The desire was to test the direct shear samples at normal stresses of roughly 0.5x, 1x, and 2x the overburden stress. For the two clay-filled samples, this level of stress was excessive and would have resulted in the extrusion of the clay just due to the application of the normal stress. Consequently, a decision was made to test the first sample (103A) at 20, 40, and 80 psi. During this test the clay filling squeezed out of the interface excessively during the application of the 80 psi normal stress. By the end of the test the two bounding rock faces were touching. (See the pencil pointing to this location in the post-test photograph.) The second sample (103B) was tested at lower normal stresses – 10, 20, 40 psi. In this test, the clay still squeezed out of the joint, but enough remained confined within the joint so as to prevent the two joint sides from coming into contact.

For the two clay filled joint tests, only one three-stage suite of tests was performed. The clay had been squeezed out of the joint so much that a second, suite of tests could not be performed. In both of these tests, the samples behaved in an unconsolidated, undrained manner. There appeared to be little if any strengthening due to the application of normal stress, in particular with Sample 103B. It may be that the small amount of strengthening of Sample 103B was simply due to strain hardening rather than a result of the application of additional normal stress. It is curious that the Sample103A demonstrated a marked frictional behavior compared to Sample 103B. It may be that Sample 103A involved more sample rotation and thereby mobilized more strength (?), or perhaps the natural spatial variability of the clay in-filling resulted in slightly different strength parameters.

In the case of the saw-cut interface, two loading suites were performed, an “initial” and a “final” suite. For the saw-cut test, the interface exhibited significant strengthening during shear. This behavior is quite typical of saw-cut interfaces of hard rock. Soft rock behaves in a contrary manner, typically maintaining its initial strength or slightly decreasing its strength with shear displacement. It should be noted that the nature of the interface changes from the initial to the final stages. In the initial stage, the surface is characterized by a small amount of roughness, on the order of the scratches that are made by the fine diamond grinding disk. By the end of the test, the interface is polished to the extent that light can be reflected off its surface. (See the photographs for the polished surface.)

The saw-cut interface exhibited marked stick slip behavior. This behavior is consistent with other saw-cut tests that I have performed. The behavior is a result of differing friction angles (static vs. dynamic), the high stiffness of the saw-cut interface, and the low shear stiffness of the shear box. (In the case a natural joint, I expect that the asperities arrest a slip event as the stresses are transferred from failing asperities to other asperities.) For these saw-cut test results, the stick slip peaks were chosen to represent the static friction angles of the rock. In a previous testing program, a number of saw-cut concrete specimens were sheared with similar behavior. In that case, the displacement rate was increased gradually and it was found that the magnitude of the slip events reduced, with the extrema asymptotically approaching the average value of the extrema. I would therefore interpret the average of the extrema to be the dynamic friction angle.

The following table summarizes the direct shear test results:

Direct Shear Test Results

Boring/ Sample #	Depth (ft.)	Description	Shear Intercept (psi)	Friction Angle (deg.)
H-107-06 #103A	84.0-84.9	Planar clay filled joint in dark gray meta-lapilli tuff. 3/8" thick soft light brown clay in-filling.	1.9	7.8
H-107-06 #103B	84.0-84.9	Planar clay filled joint in dark gray meta-lapilli tuff. 3/8" thick soft light brown clay in-filling.	3.6	3.2
H-107-06 #103A	84.0-84.9	Saw-cut and ground interface in dark gray meta-lapilli tuff.	4.5[i] 6.0[f]	30.6[i] 39.4[f]

Notes: i. Initial strength parameter
f. Final strength parameter

If you have any questions regarding these test results or the test procedures, please feel free to contact me so that we can discuss any of your concerns.

for GeoTest Unlimited

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Dr. Anders Bro


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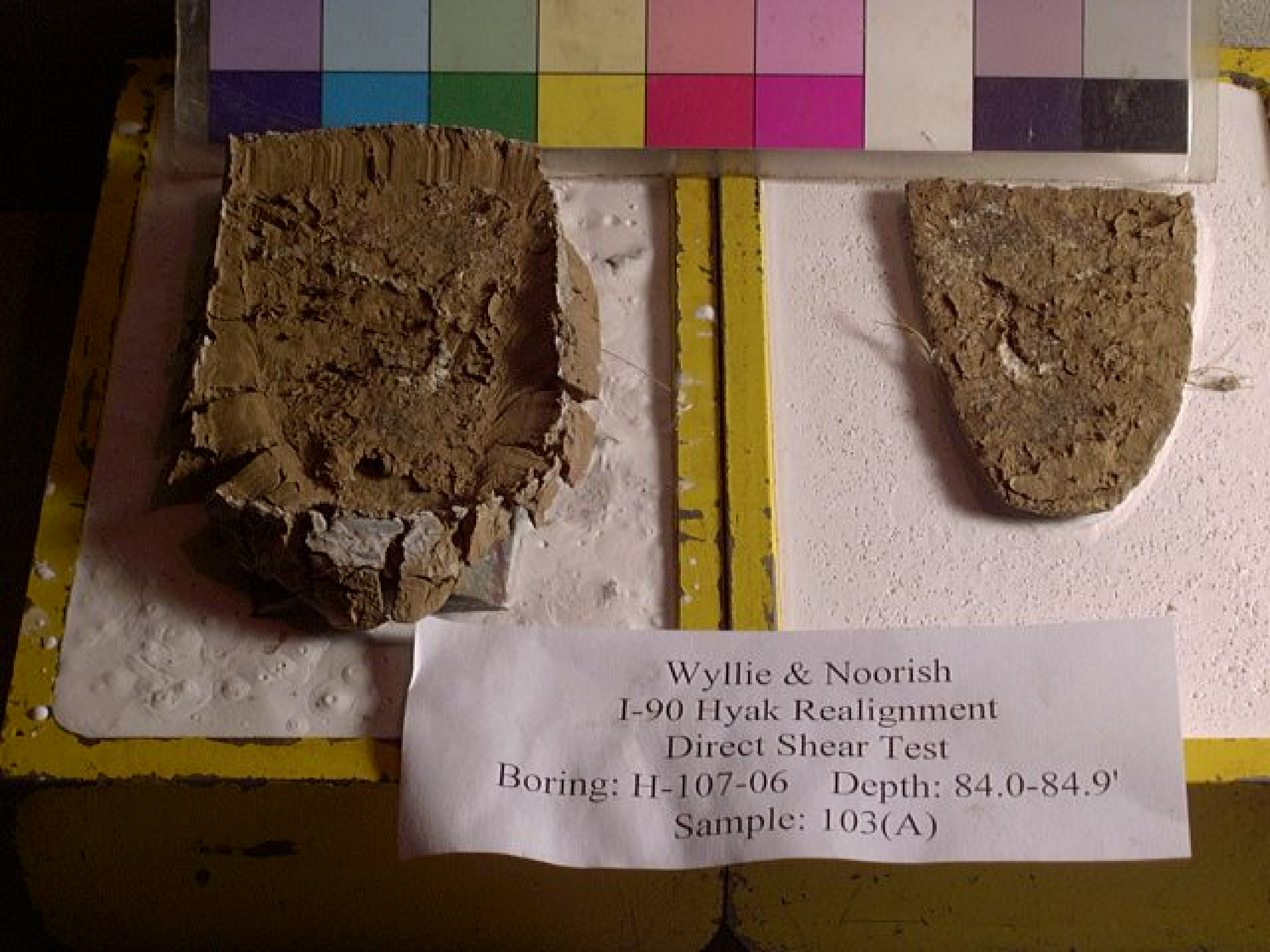
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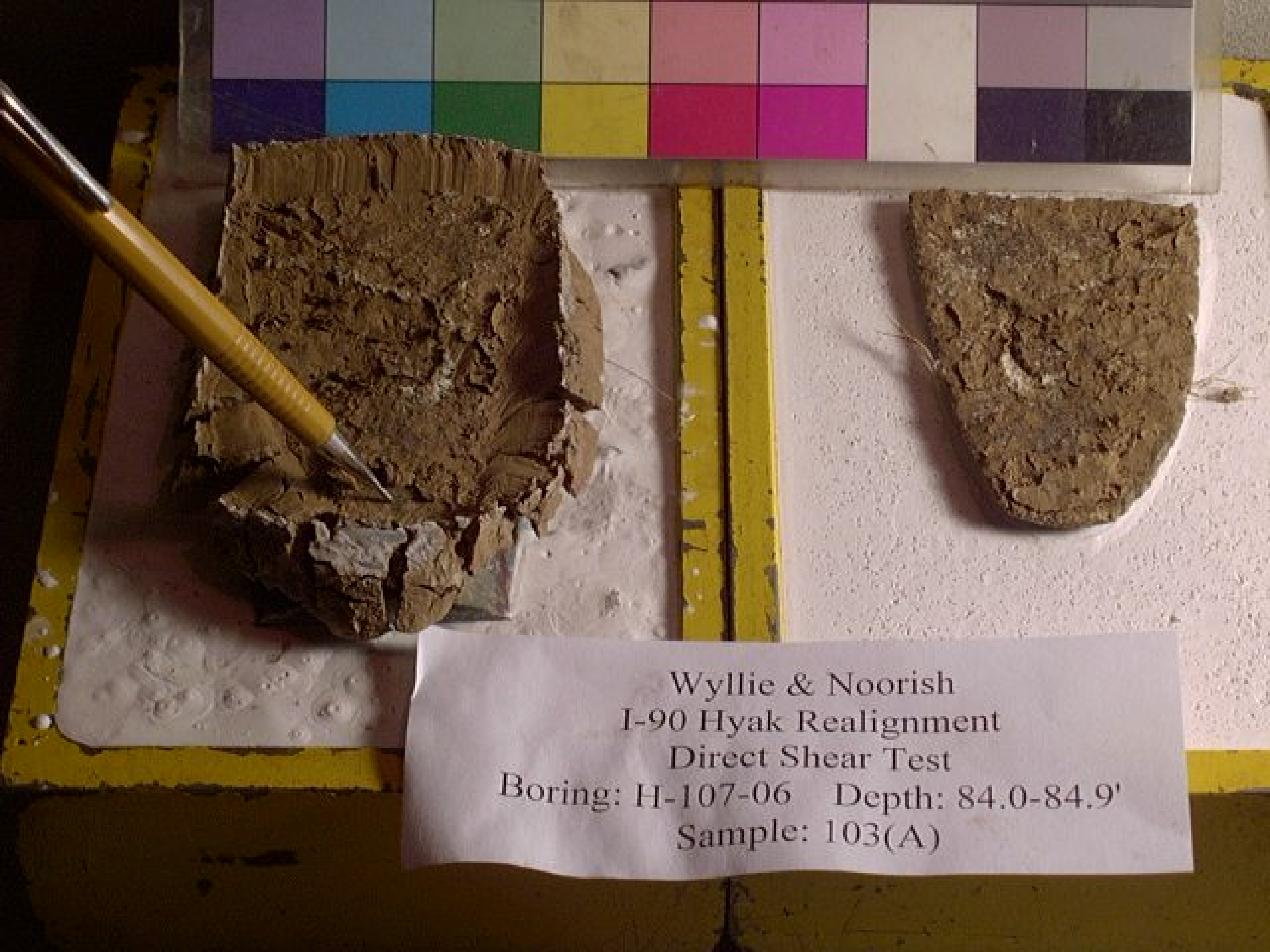
Sample: 103(A)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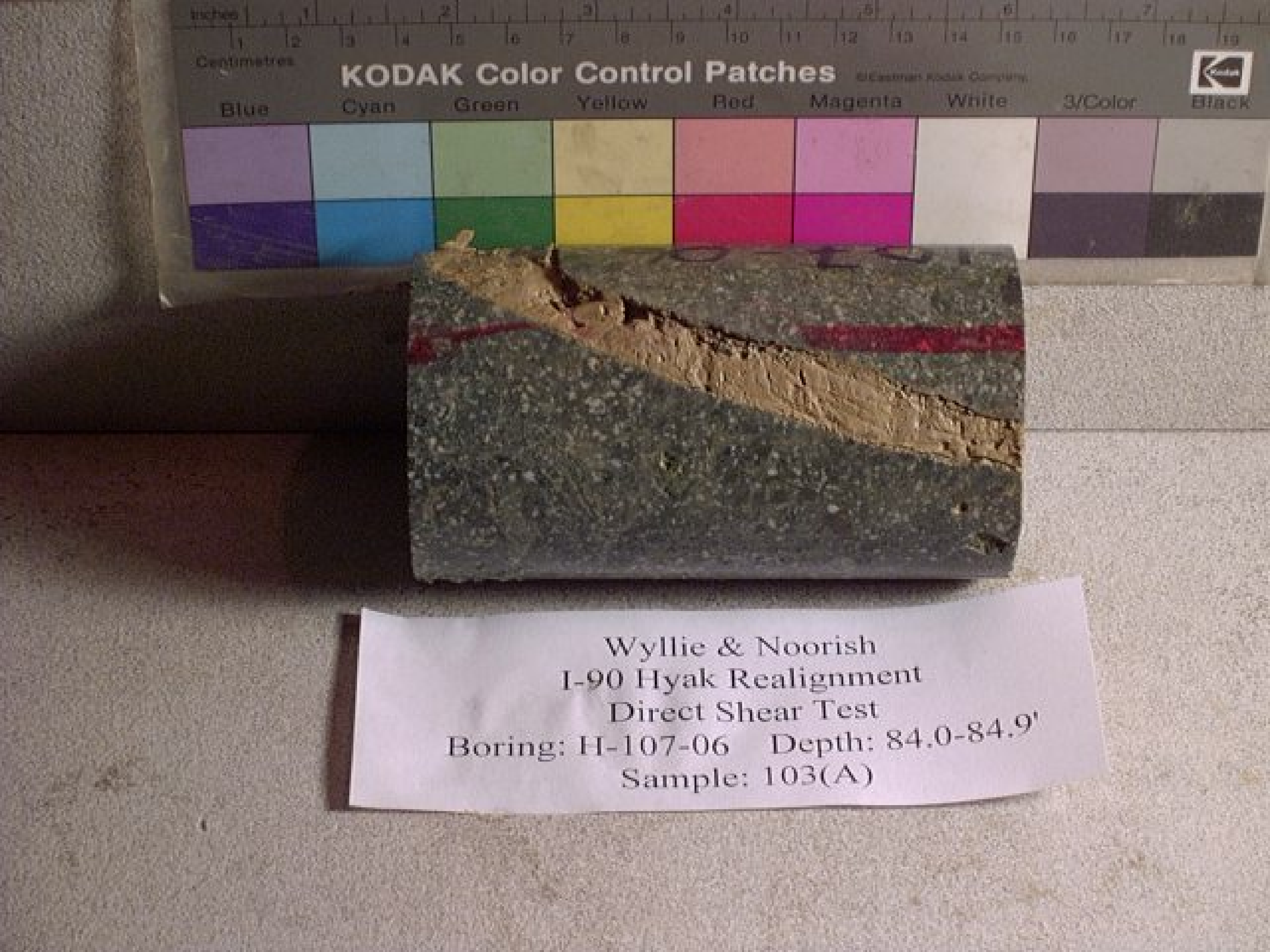
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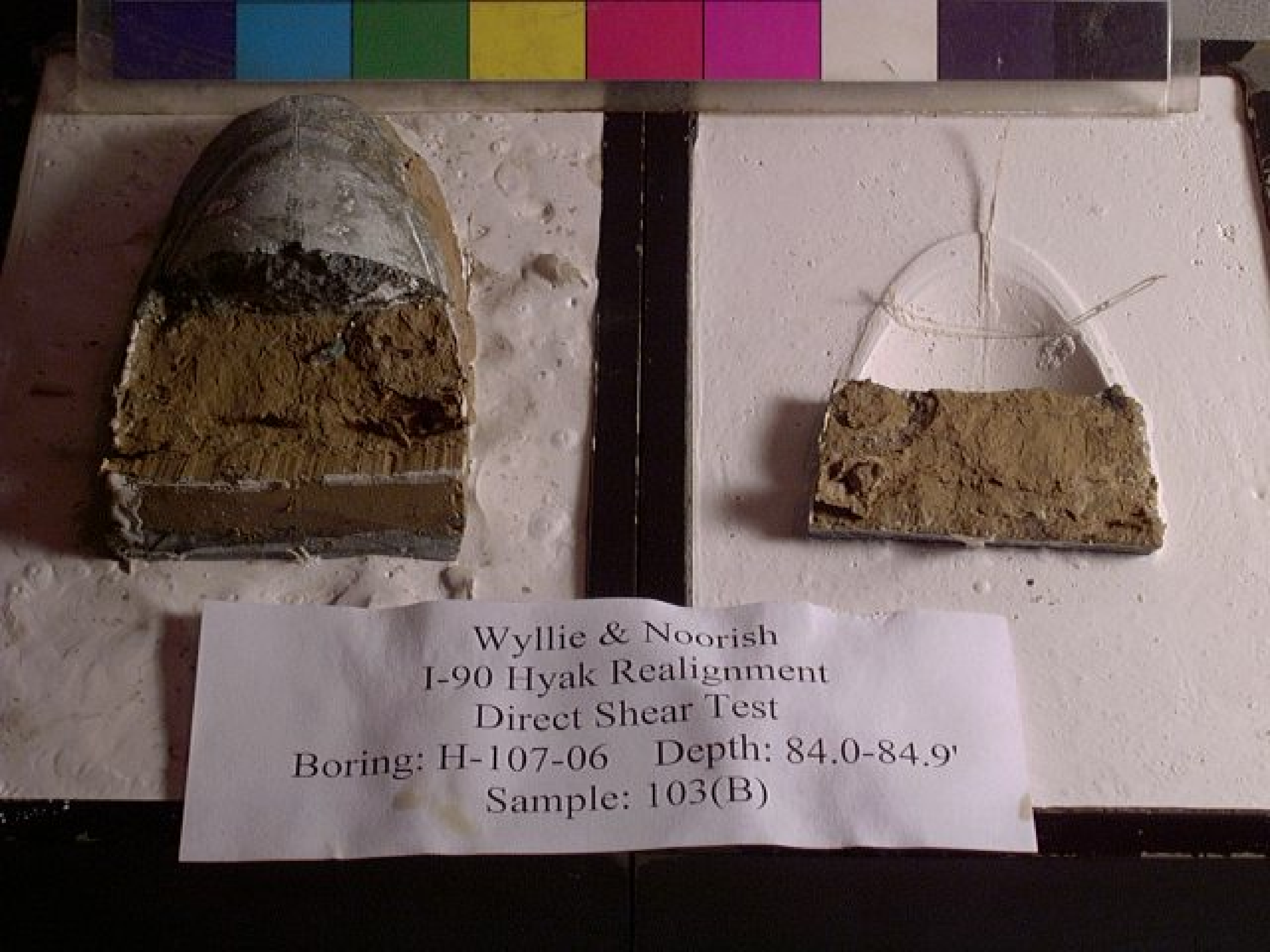
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Direct Shear Test
Boring: H-107-06 Depth: 84.0-84.9'
Sample: 103(B)


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Boring: H-107-06
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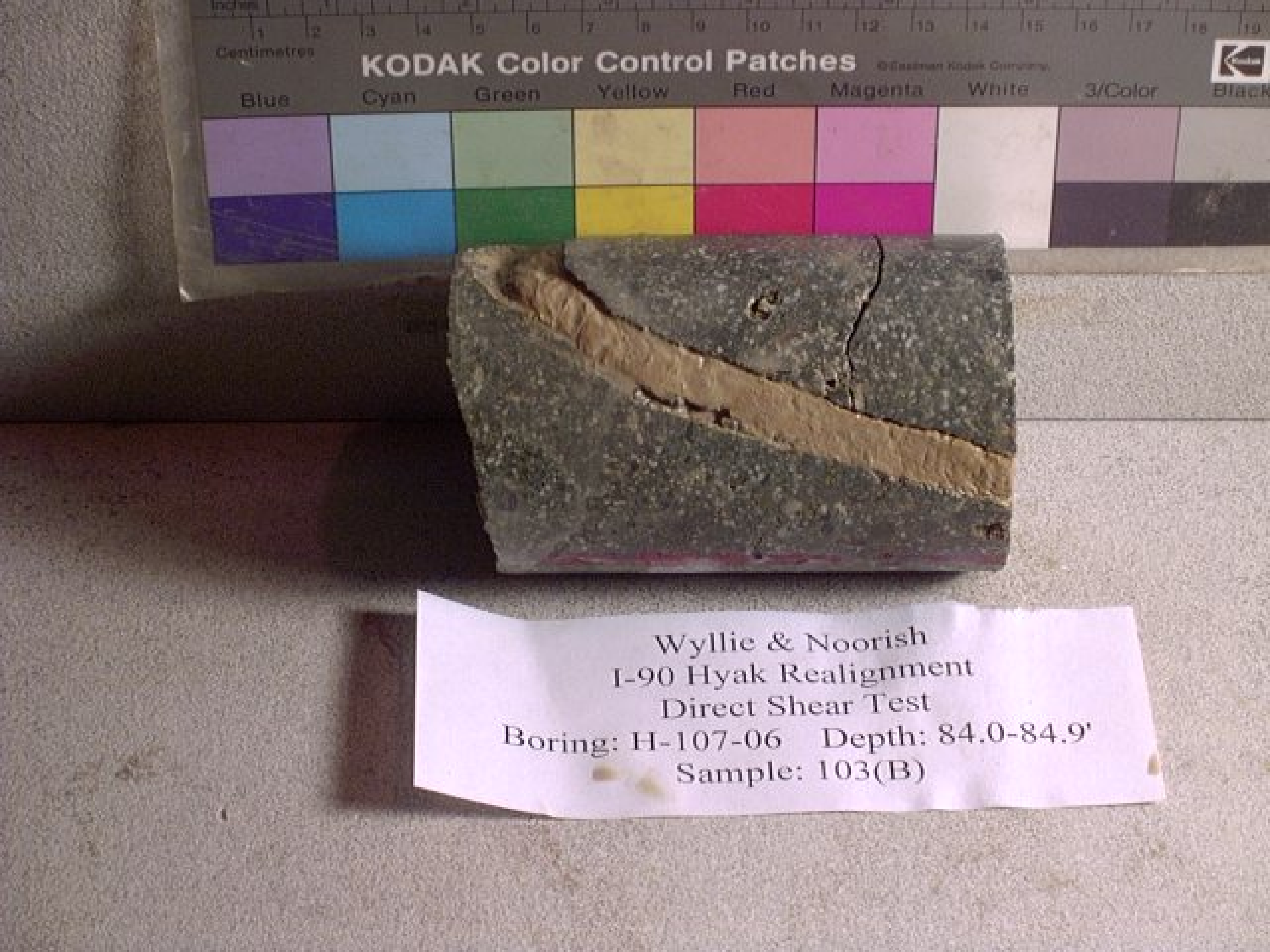
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Sample: 103(B)


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Wyllie & Norrish
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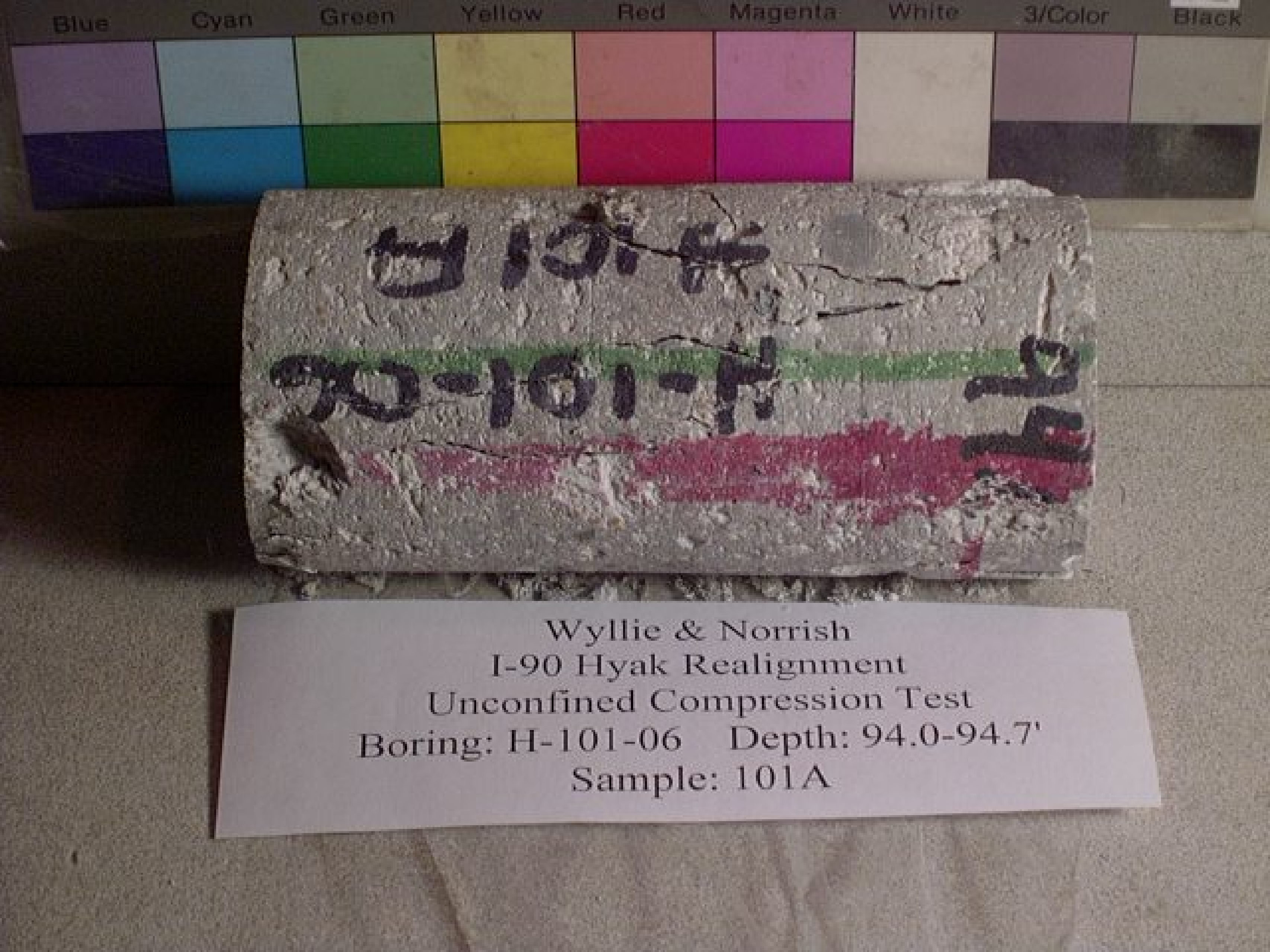
Direct Shear Test
Boring: H-107-06 Depth: 84.0-84.9'
Sample: 103SC


Wyllie & Norrish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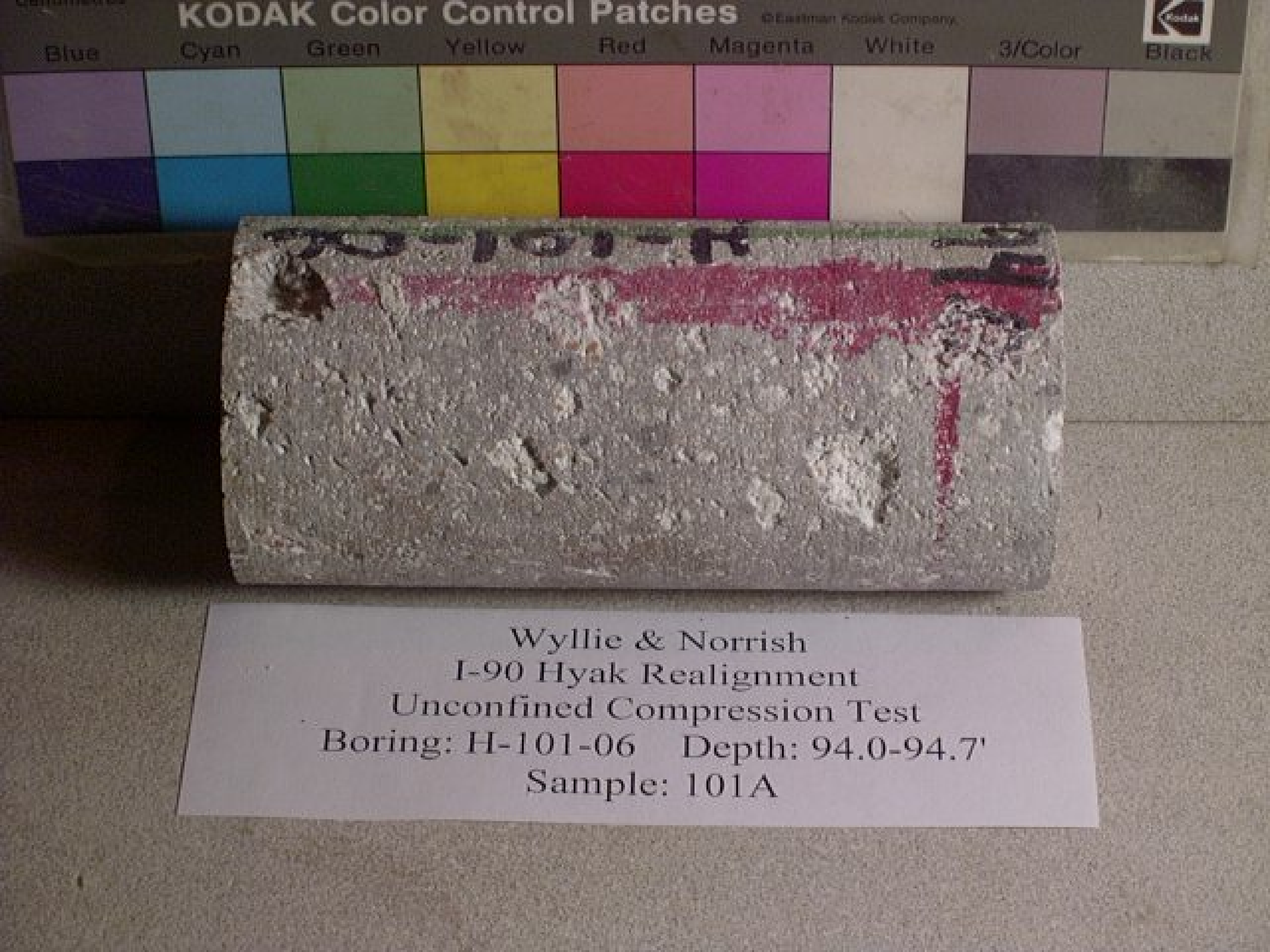
Sample: 101A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Unconfined Compression Test
Boring: H-101-06 Depth: 94.0-94.7'
Sample: 101A


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I-90 Hyak Realignment
Unconfined Compression Test
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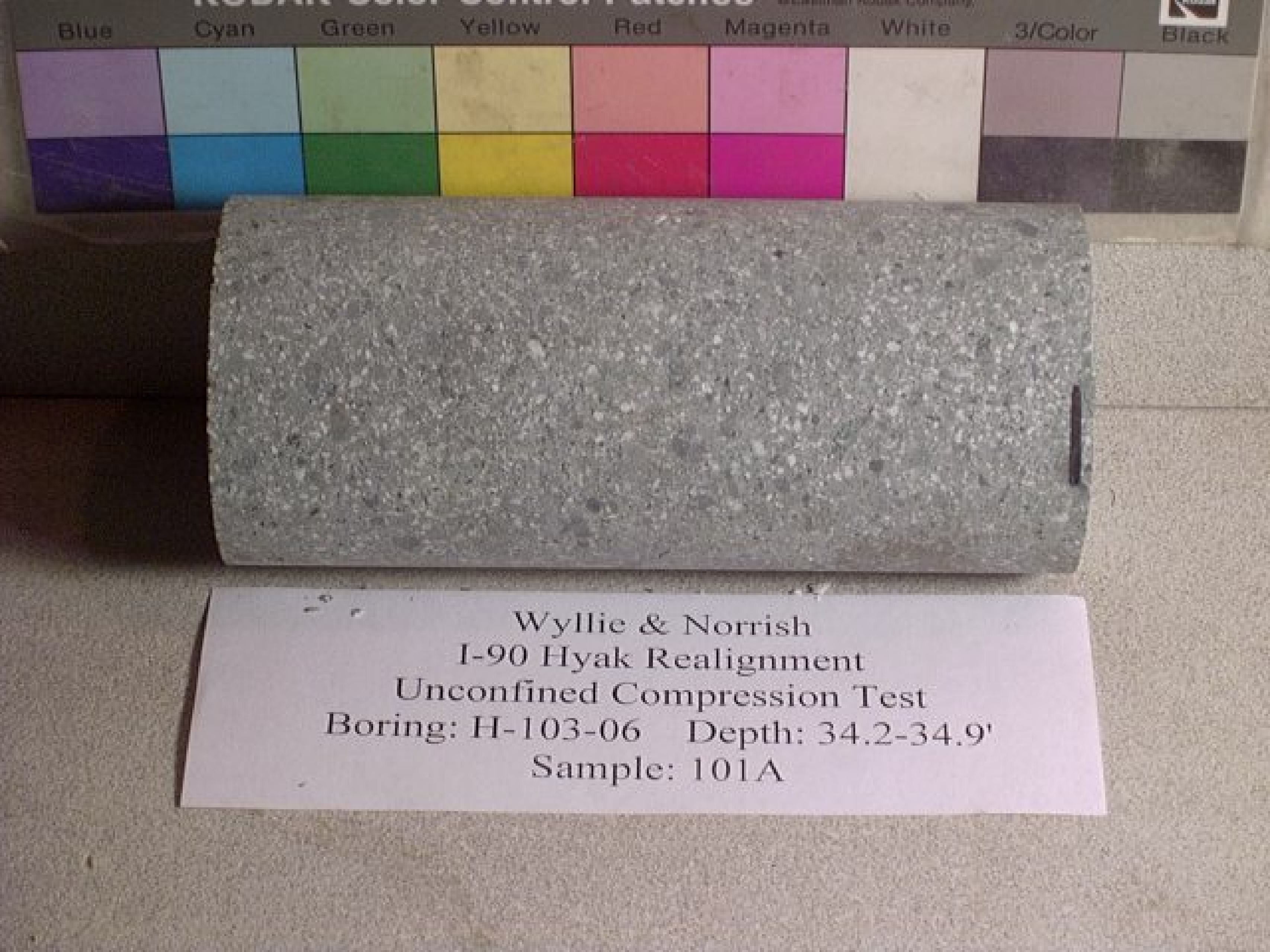
Sample: 101A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Boring: H-103-06 Depth: 34.2-34.9'
Sample: 101A


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Unconfined Compression Test
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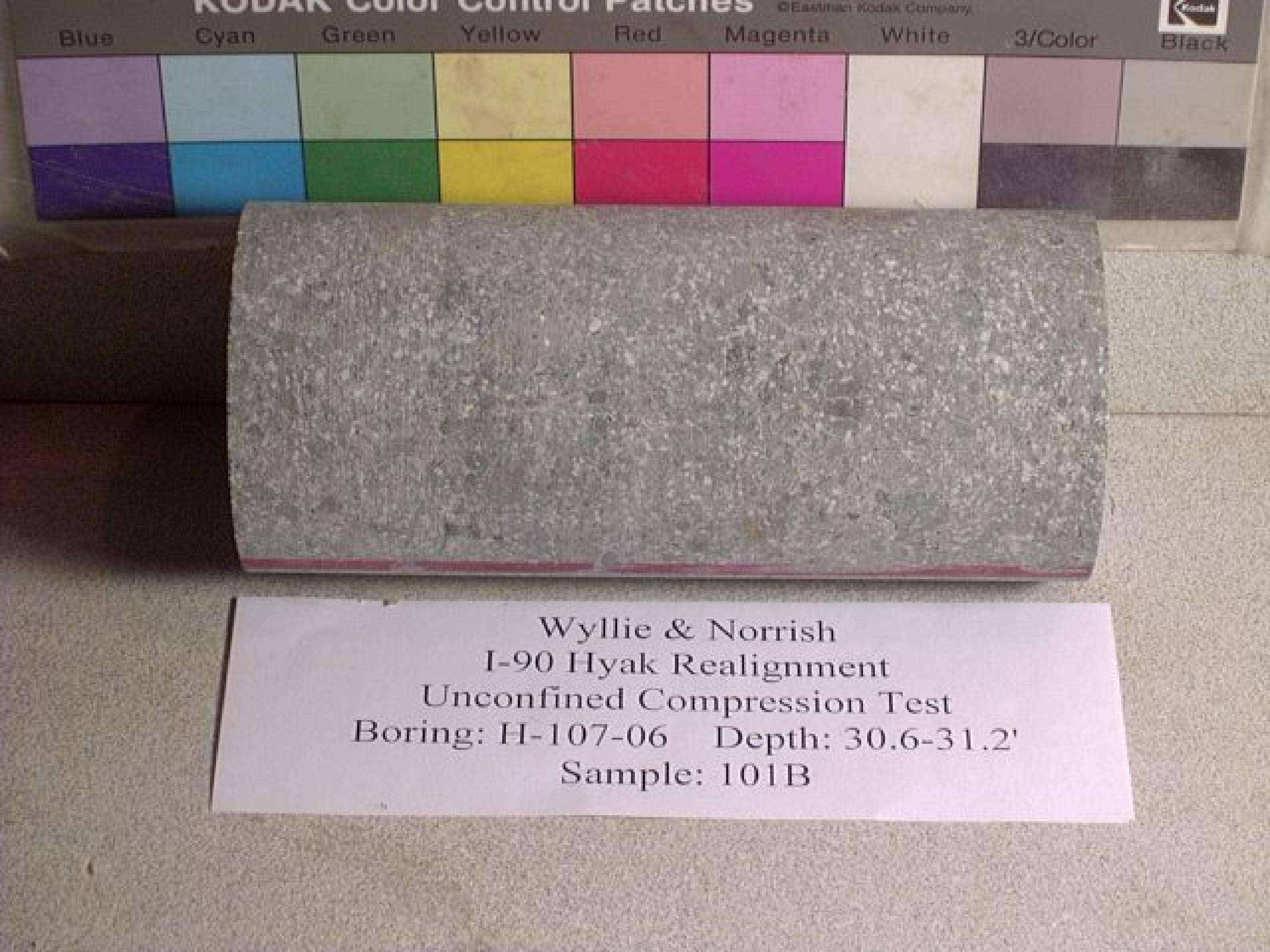
Sample: 101B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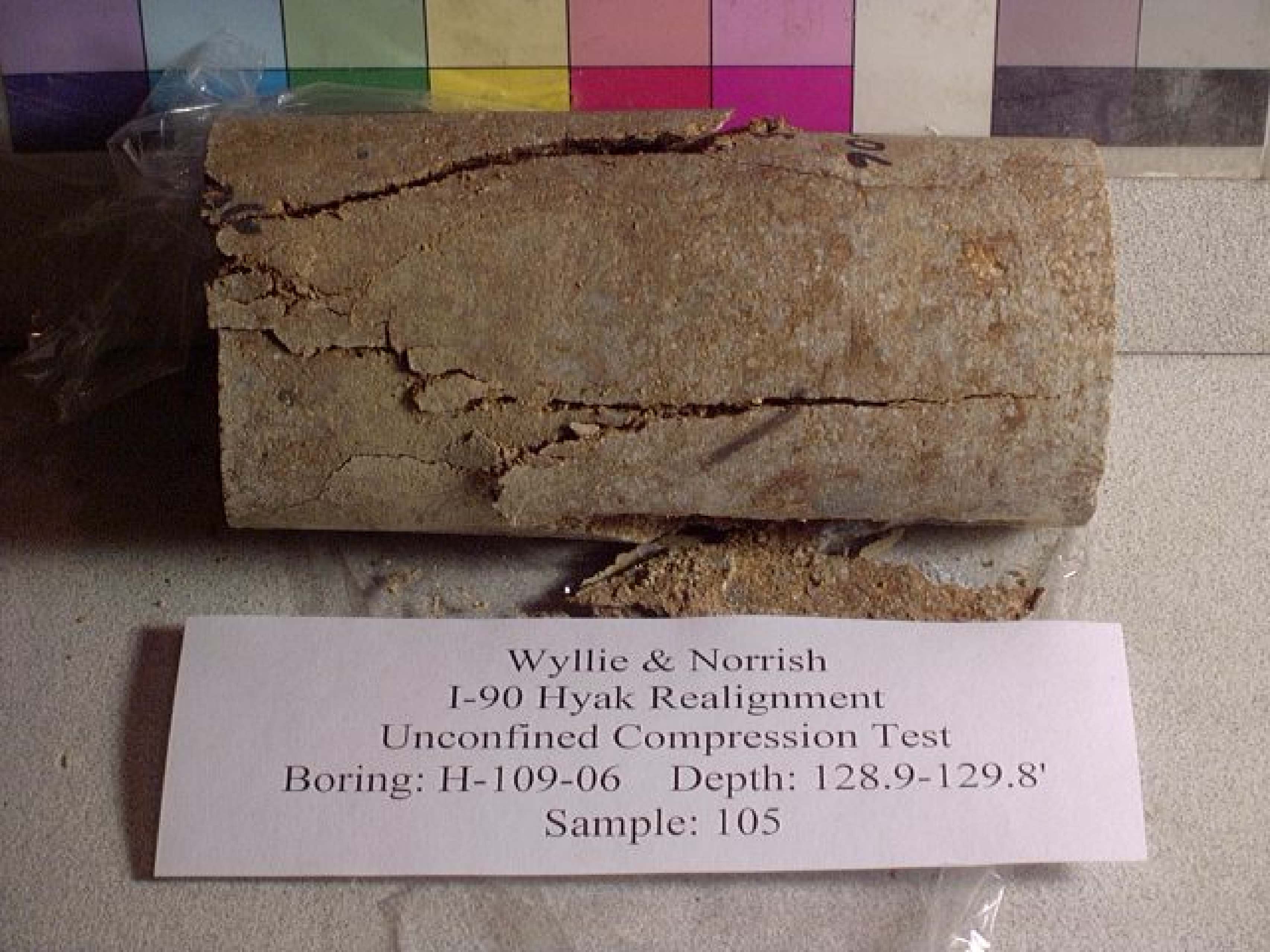
Sample: 101B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Sample: 105


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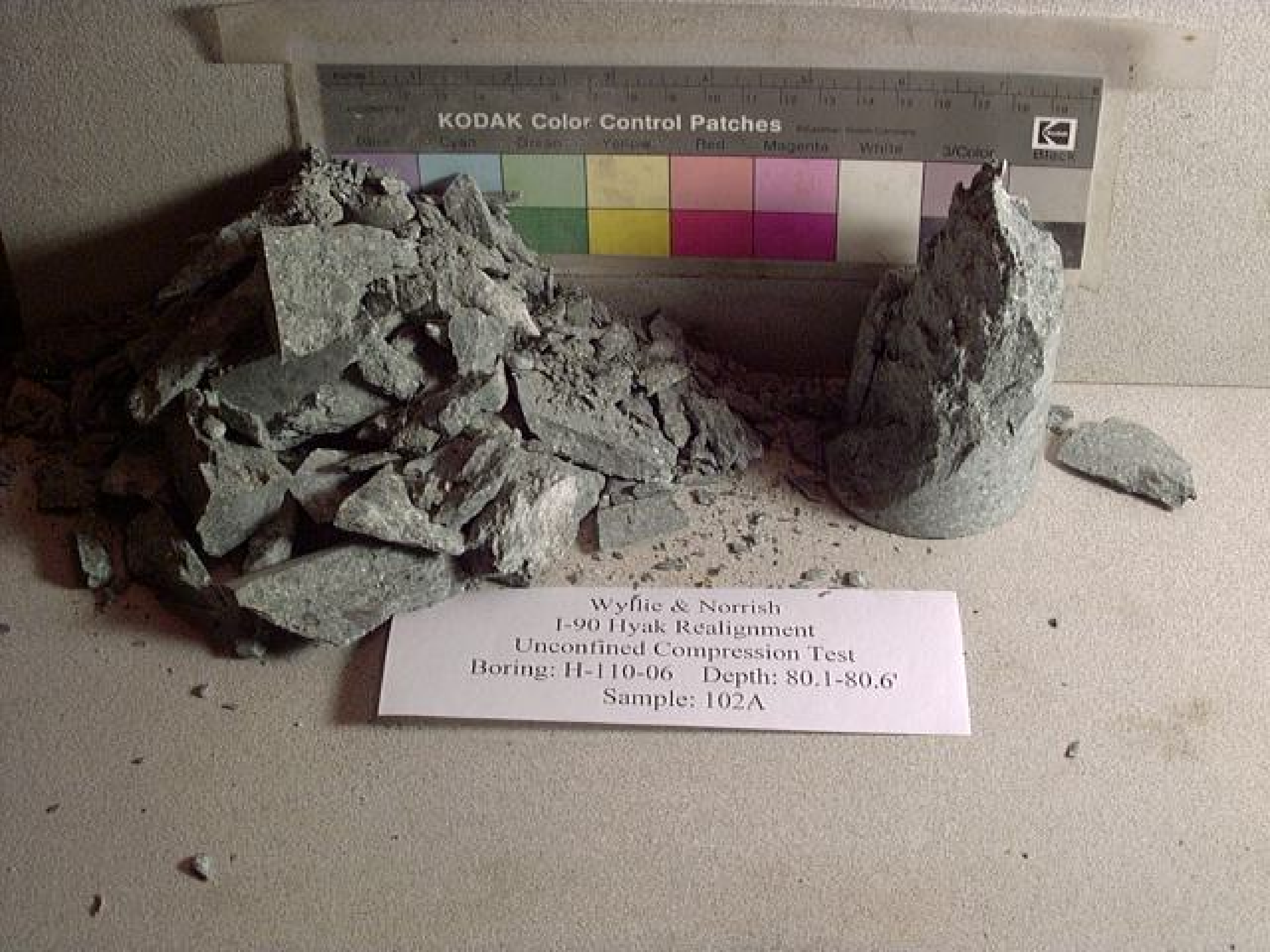
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Unconfined Compression Test
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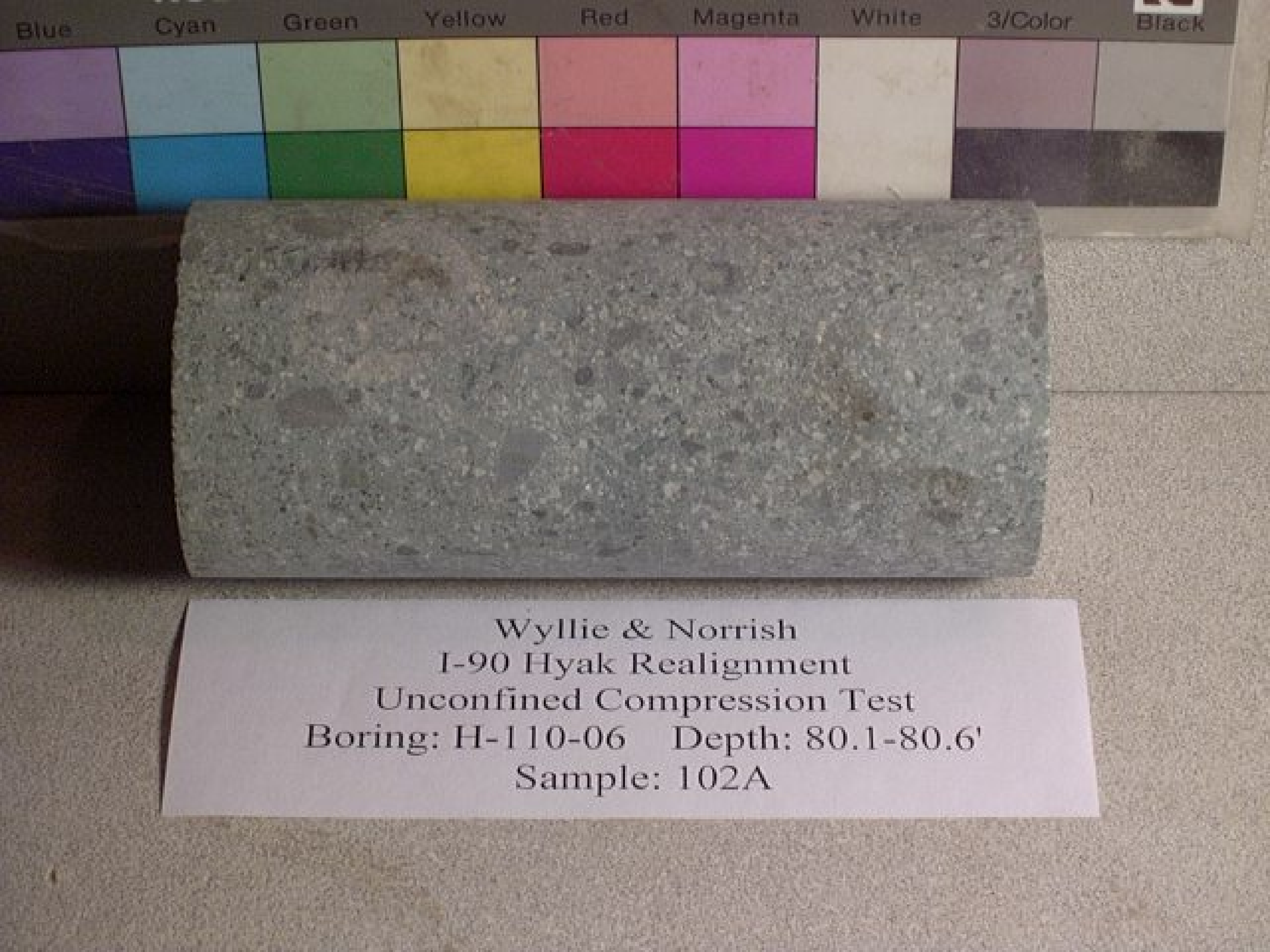
Sample: 102A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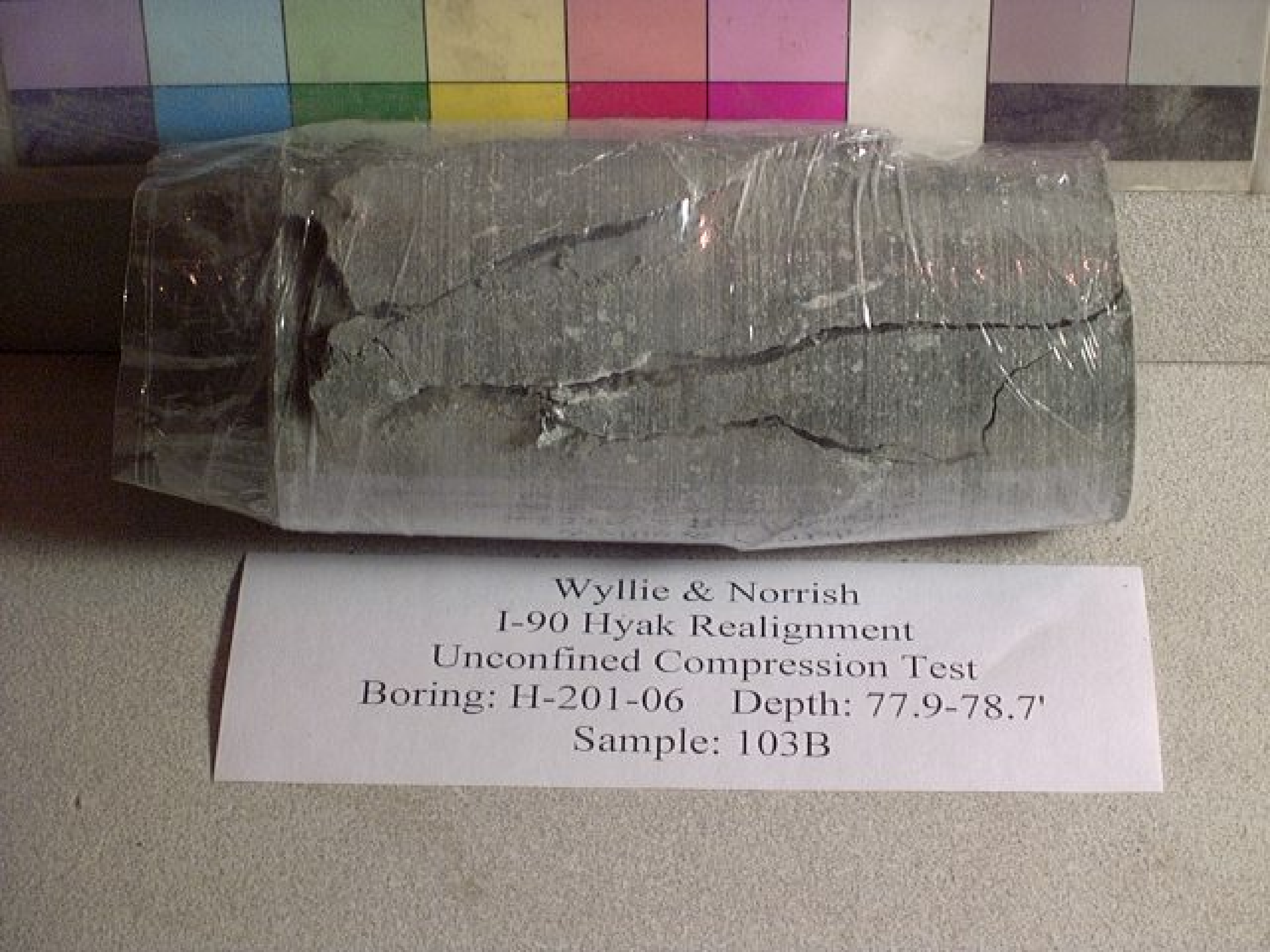
Sample: 102A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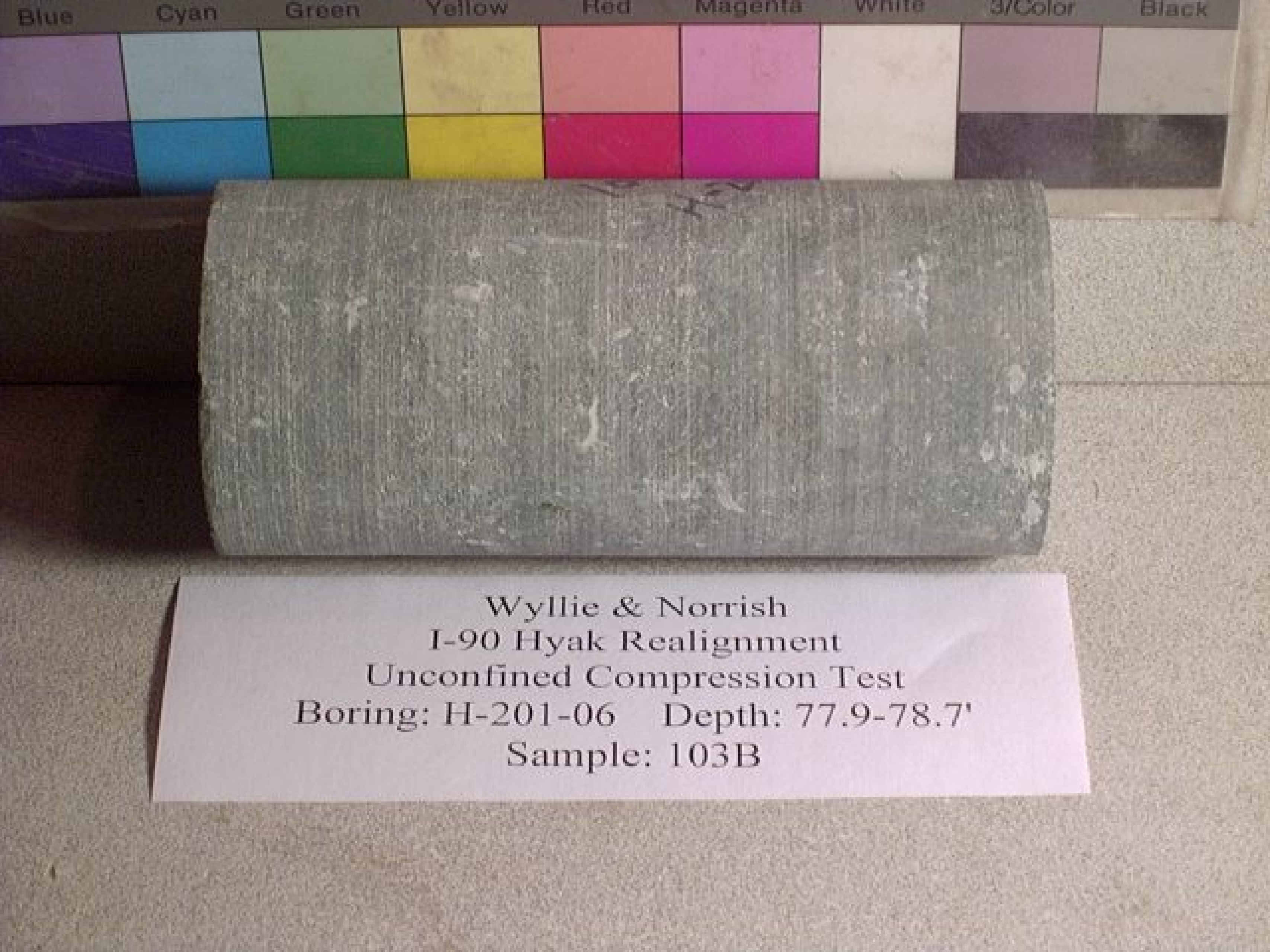
Sample: 103B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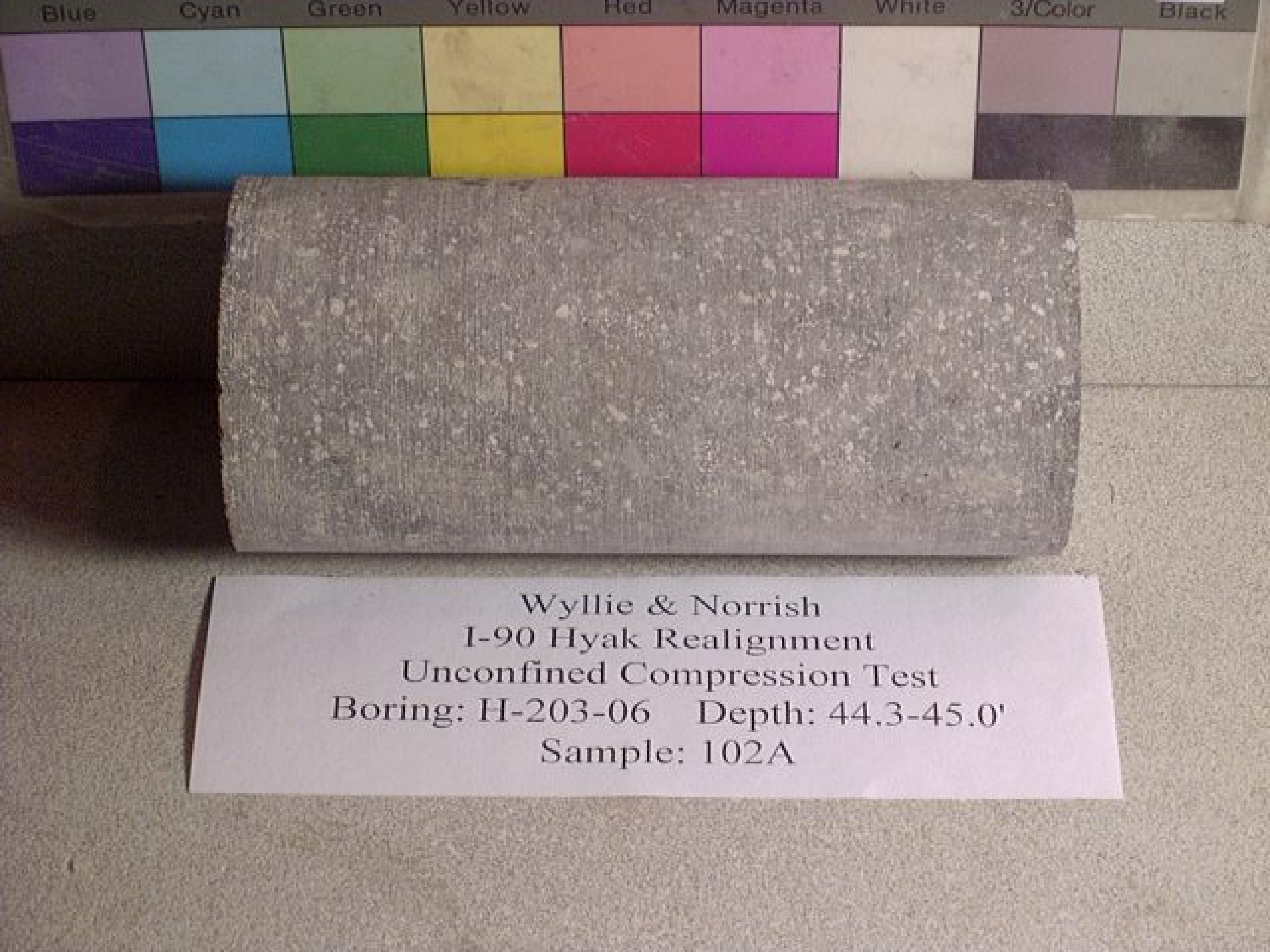
Unconfined Compression Test
Boring: H-201-06 Depth: 77.9-78.7'
Sample: 103B


Wyllie & Norrish
I-90 Hyak Realignment
Unconfined Compression Test
Boring: H-203-06 Depth: 44.3-45.0'
Sample: 102A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Wyllie & Norrish
I-90 Hyak Realignment
Unconfined Compression Test
Boring: H-203-06 Depth: 44.3-45.0'
Sample: 102A

October 15, 2007

Rock Testing
I90 Hyak Extension

Wyllie & Norrish Rock Engineers
17918 NE 27th St.
Redmond, WA 98052

Dear Norm,

This letter report summarizes the unconfined compression, point load, and direct shear tests performed on the samples that you had sent to my lab a number of weeks ago. The report summarizes the test results along with some comments about the testing program that you might find helpful in interpreting the results. The standard test procedures used for these tests are appended to this letter, along with a compact disk containing the data files and photographs of the pre-and post-test samples.

Of the 23 samples sent to me, three filled interfaces were slated for direct shear testing. In addition, ten were slated for unconfined compression tests along with companion axial and diametral point load tests using the remaining 10 samples.

Unconfined Compression and Point Load Testing

The objective of this testing program was to perform a set of unconfined compression tests along with companion axial and diametral point load tests so that a reasonable correlation between the test values could be developed. For each pair of samples (labeled –A and –B) the least fractured samples were chosen for the unconfined compression tests. An effort was also made to cut unfractured samples for the axial point load tests. It was felt that it should be possible to find a suitable diametral point load sample from the remaining core.

The samples did not appear to be particularly hard when cut with the diamond saw. In a few cases, the samples appeared to be slightly friable, the edges of the cut sample being easily fractured during sawing. In one case, Sample 03-102B, the medium grained greenish gray material appeared to be quite weak and was relatively easily rubbed from the sample. In retrospect, this material may have been slightly altered compared to the dark gray fine grained material.

The materials were generally metamorphosed and were of volcanic origin. Some of the medium gray lapilli tuffs were not very dense (154.6-158.1 pcf) and I wonder if these may not have been metamorphosed. Perhaps if they have, they have been subjected to only a very low grade of metamorphism. These low densities are unusual for a metamorphic rock. On the other hand, their relatively high strength might argue the case that they have been metamorphosed.

The test results are tabulated as follows:

Unconfined Compressive Strength and Point Load Test Results

Boring/ Sample #	Depth (ft.)	Description	Density (pcf)	Corrected Point Load (psi)	UC Strength (psi)
RKS-01-07 01-102A	44.3-44.8	Dark gray meta-andesite with a healed calcite vein and calcite inclusions.		974/757[di]	
RKS-01-07 01-102B	44.8-45.5	Dark gray meta-andesite with a healed calcite vein and calcite inclusions.	171.6	553[a]	12,380
RKS-03-07 03-102B	71.6-72.3	Dark gray fine grained and dark greenish gray medium grained meta-lapilli tuff.	165.1	195[a] 370[d]	5113
RKS-04-07 04-101A	24.3-25.2	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.		569[a]	
RKS-04-07 04-101B	25.2-26.0	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.	160.2	774[d]	16,725
RKS-05-07 05-101A	15.1-15.7	Dark purplish gray meta-basalt with no apparent planes of weakness.		192[a] 288[d]	
RKS-05-07 05-101B	15.7-16.4	Dark purplish gray meta-basalt with no apparent planes of weakness.	156.7		10,599
RKS-05-07 05-103A	59.5-60.1	Dark purplish gray and dark greenish gray breciated andesite with no apparent planes of weakness.	165.6		13,961
RKS-05-07 05-103B	60.1-60.7	Dark purplish gray and dark greenish gray breciated andesite with no apparent planes of weakness.		562[a] 424[d]	
RKS-06-07 06-101A	35.1-35.8	Dark gray meta-andesite with quartz healed fractures and tight fractures.	174.6	611[a]	10,946
RKS-06-07 06-101B	35.8-36.5	Dark gray meta-andesite with quartz healed fractures and tight fractures.		518[d]	
RKS-08-07 08-101A	10.0-10.7	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.	158.1	364[a]	9795
RKS-08-07 08-101B	10.7-11.3	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.		321[d]	

RKS-09-07 09-102A	41.3-41.9	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.		262[a] 234[d]	
RKS-09-07 09-102B	41.9-42.6	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.	156.6		10,040
RKS-10-07 10-2A	74.1-74.8	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.	154.6	279[a]	10,674
RKS-10-07 10-2B	74.8-75.4	Medium gray meta-welded lapilli tuff with no apparent planes of weakness.		128/206[a]	
RHS-11-07 11-101A	64.1-64.8	Medium gray meta-welded lapilli tuff with a few tight fractures.	161.3		11,100
RHS-11-07 11-101B	64.8-65.4	Medium gray meta-welded lapilli tuff with a few tight fractures.		254[a] 429[d]	

Notes: a. Axial Point Loading
d. Diametral Point Loading
i. Invalid – failure did not pass through both points of loading.

With the exception of Sample 03-102B, the unconfined samples were quite competent with strengths generally above 10,000 psi, ranging from 9795 to 16,725 psi. Excluding the two extreme strengths (5113 psi and 16,725 psi), the average strength was 11,187 psi and the strengths ranged from 9795 to 13,961 psi. This tight band of strengths was quite unusual considering the variety of materials. Unlike other rock testing programs, there did not appear to be a clear correlation between rock density and rock strength.

With regard to the point load tests, a few tests were repeated due to the unusual test results. In the case of Sample 01-102A, the sample appeared to be quite hard and the loading points slipped off the sample before the sample could break properly, resulting in a chip created on the side of the sample. This sample was retested in another location, resulting in the same invalid mode of failure. Two tests were also performed on Sample 10-2B as the first result seemed to be unusually low. I believe that the second result is more representative of this rock. All of the sample failed through intact rock and the strengths did not appear to be influenced by discontinuities.

Direct Shear Testing

Three samples were slated for direct shear testing. One consisted of a highly fractured rock interface with a clay filling. The second one consisted of a single clay-filled discontinuity, and the third consisted of a thick clay layer bearing against an undulating rock contact. The first sample, Sample 06-104, posed no problem in that the sample was undisturbed and did not appear to be disturbed during sample preparation. The second sample, Sample 11-102, was greatly disturbed during sample preparation. When cutting the very hard parent rock, the clay filling became moist, one of the sample halves fractured along weak discontinuities, and the sample came apart. After cutting, the sample was carefully reassembled and successfully tested. The third sample, Sample 02-201, was unsuitable for testing in my rock shear testing apparatus. The rock-clay contact was greatly disturbed and the two sample halves did not conform to each other. On viewing the sample, particularly in light of the level of stress to which the sample would be subjected and the resultant squeezing and deformation of the clay portion of the sample, I felt the results would not properly represent the in-situ interface, and so did not recommend testing this sample.

The remains (the cuttings and the tested portions) of these three samples were sent to Sunland Analytical Lab in Rancho Cordova for corrosivity testing. It should be noted that they require a minimum sample weight for their tests and there may be some problems with obtaining good test results with the limited volume of clay material from these samples.

The following table summarizes the direct shear test results:

Direct Shear Test Results

Boring/ Sample #	Depth (ft.)	Description	Shear Intercept (psi)	Friction Angle (deg.)
RKS-06-07 06-104	80.9-81.6	Breciated shear zone with hard broken meta-andesite interspersed in tannish gray clay.	1.3[i] 2.3[f]	23.2[i] 23.0[f]
RKS-11-07 11-102	107.3-107.8	Planar joint with firm brown clay filling in meta-welded lapilli tuff.	4.1[i] 4.1[f]	10.1[i] 12.3[f]

Notes: i. Initial strength parameter
f. Final strength parameter

Both of these direct shear samples resulted in some quite interesting test results that required some thought when it comes to reducing the test measurements.

Sample 06-104 consisted of a shear zone consisting of broken rock, appearing as slabs parallel to the main shear plane, with clay separating the rock pieces. Unlike a typical filled discontinuity, the broken rock pieces could rotate and modify the interface strength as shear displacements developed. This interaction was evident during the initial second and third stages and well as the final third stage. During the initial second stage, the strength appeared to be quite low. This low strength was either due to error on my part, by not allowing the test to proceed to a large enough shear displacement (although the shear strength did start to drop just before stopping this second stage) or it did represent the shear strength of the clay without the rock blocks bridging the two sides of the shear zone. I expect that the high initial third stage strength represented a rock-to-rock contact strength that was modified by the presence of the clay. I have chosen, somewhat arbitrarily, to simply use the linear approximation of these three measured strengths to represent the failure envelope of the initial shear of the interface. This representation may be incorrect and it may be more proper to use the first and second stage initial strengths to represent the clay strength without the rock-to-rock interaction.

During the final stages, quite regular first and second stage strengths developed. However something occurred during this final third stage, possibly a major rotation of one of the rock blocks, that significantly weakened the interface. This occurrence was also accompanied by a much more extreme irregularity in the stress-displacement trace, something that would be characteristic of a rolling block within the interface. I expect that for the purposes of creating a failure envelope that this lower strength should not be used. For the purposes of constructing the final failure envelope, the third stage strength of the initial set of loadings was used. Despite the nice alignment of the failure points, it should be recognized that there is a distinct possibility that the hard rock blocks could act in the manner of ball bearings, and allow the shear interface to be quite a bit weaker than has been expressed by this failure envelope.

Sample 11-102 behaved a bit more normally than Sample 06-104. The initial strengths were quite regular, however the final third stage strength did become a bit irregular. I expect that this irregularity might have been due to sample rotation, and perhaps the development of a rock-to-rock contact. The peak strength was discounted in the development of the final failure envelope. It was interesting to note that by the end of the test, the clay layer had developed quite distinct slickensides. Such slickensides are quite unusual as the shearing process typically disrupts the slickensides rather than developing them. I expect their development was due to the quite hard nature of the clay that filled the discontinuity.

If you have any questions regarding these test results or the test procedures, please feel free to contact me so that we can discuss any of your concerns.

for GeoTest Unlimited

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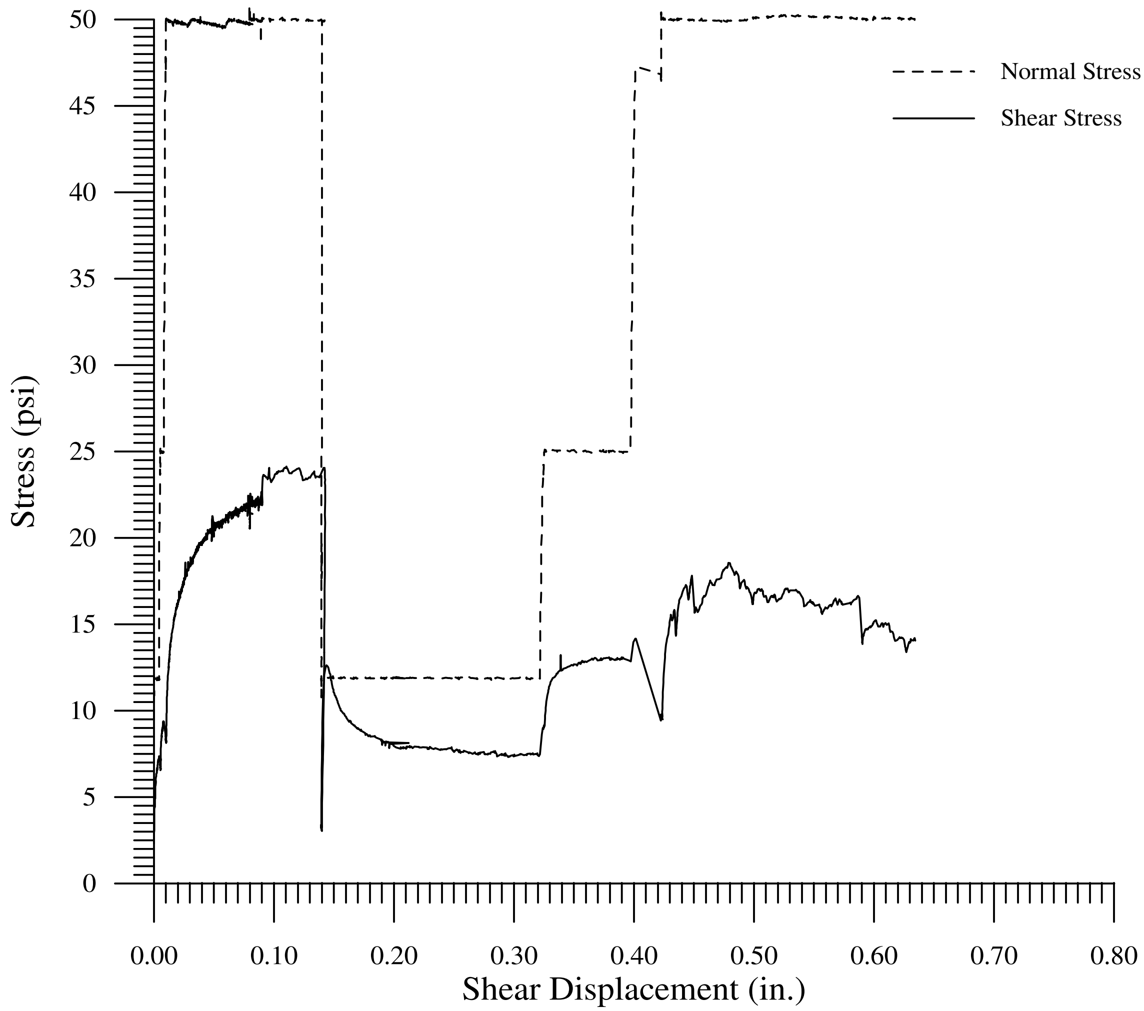
Dr. Anders Bro



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 06-104
Boring: RKS-06-07
Depth: 80.9-81.6'

DESCRIPTION

Breciated shear zone with hard broken meta-andesite interspersed in tannish gray clay.

	Normal Stress (psi)	Shear Strength (psi)
Initial	11.8	7.4
	25	9.4
	50	22.2(?)
Final	11.8	7.4
	25	12.8
	50	23.6

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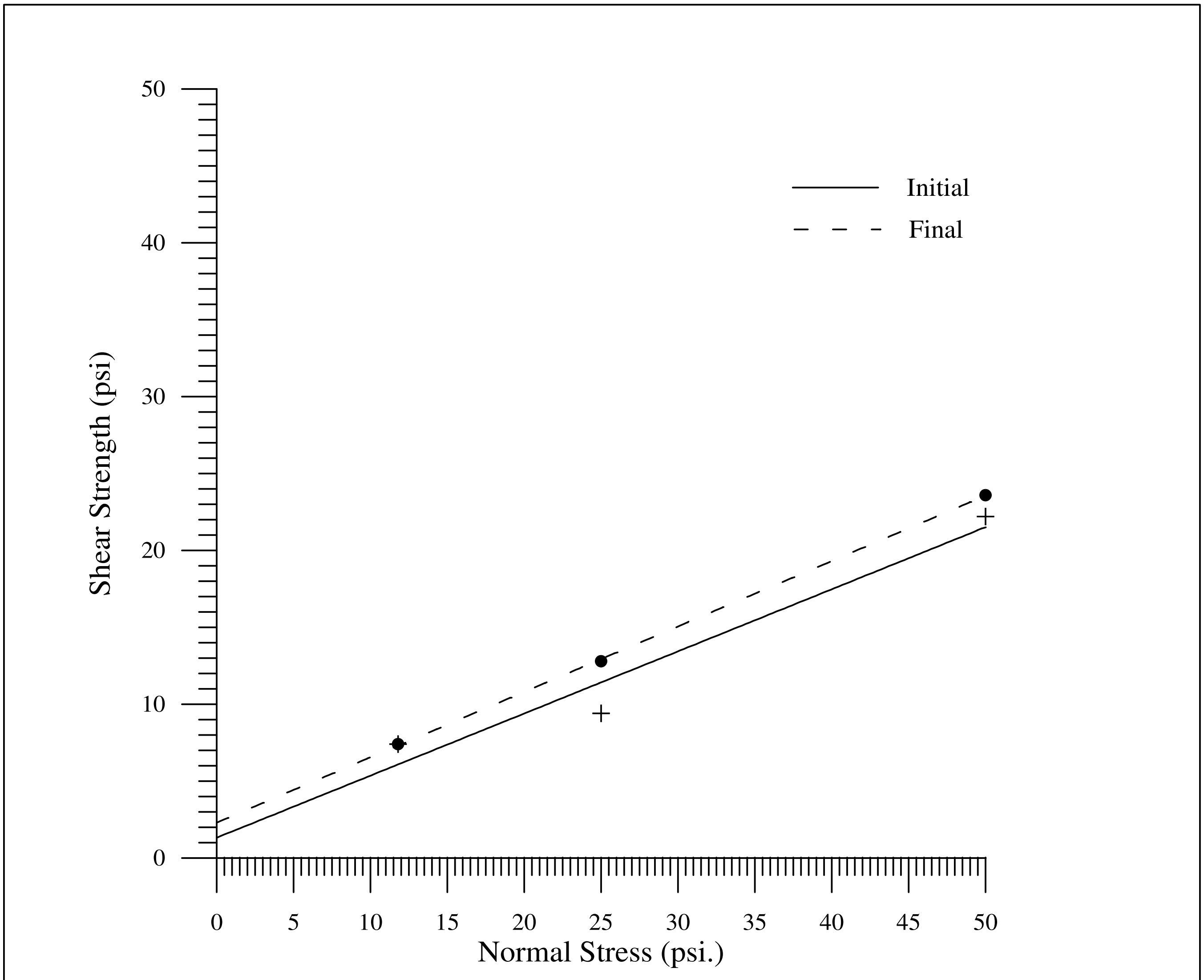
17918 NE 27th St.
Redmond, WA 98052

Project: **I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **October 11, 2007**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 06-104
Boring: RKS-06-07
Depth: 80.9-81.6'

DESCRIPTION

Breciated shear zone with hard broken meta-andesite interspersed in tannish gray clay.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	1.3	23.2
Final	2.3	23.0

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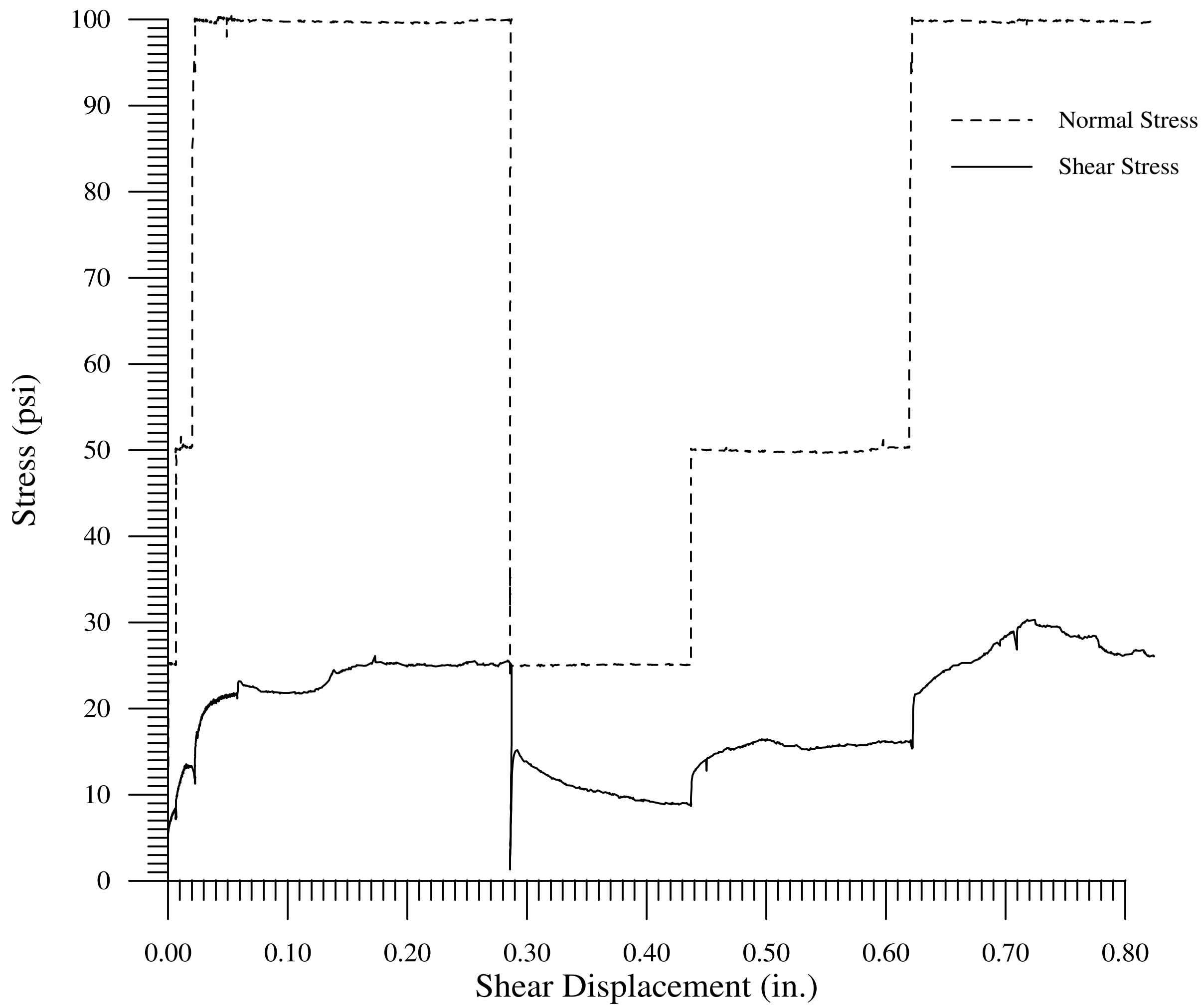

DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 11-102
Boring: RKS-11-07
Depth: 107.3-107.8'

DESCRIPTION

Planar joint with firm brown clay filling in meta-welded lapilli tuff.

	Normal Stress (psi)	Shear Strength (psi)
Initial	25	8.1
	50.3	13.6
	100	21.6
Final	25	8.8
	49.6	16
	99.6	25.4

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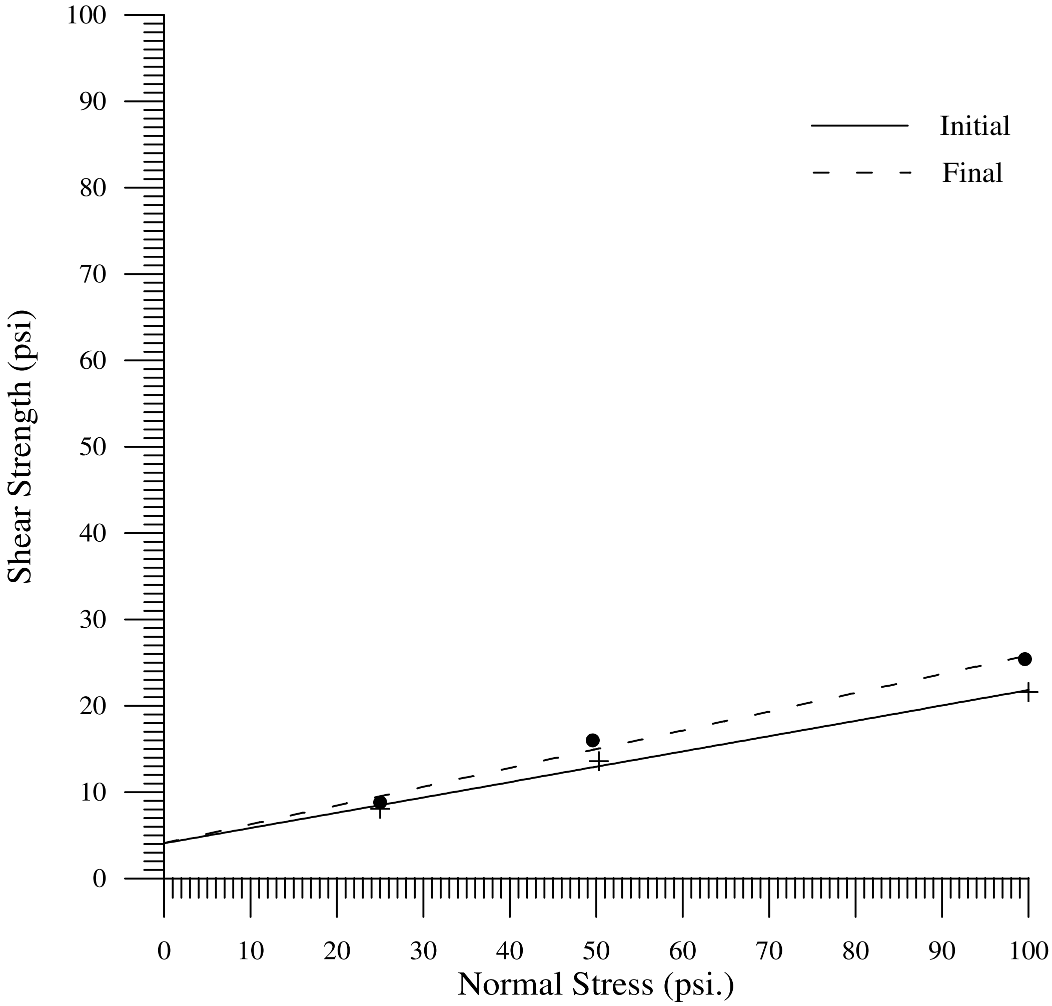

DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 11-102
Boring: RKS-11-07
Depth: 107.3-107.8'

DESCRIPTION

Planar joint with firm brown clay filling in meta-welded lapilli tuff.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	4.1	10.1
Final	4.1	12.3

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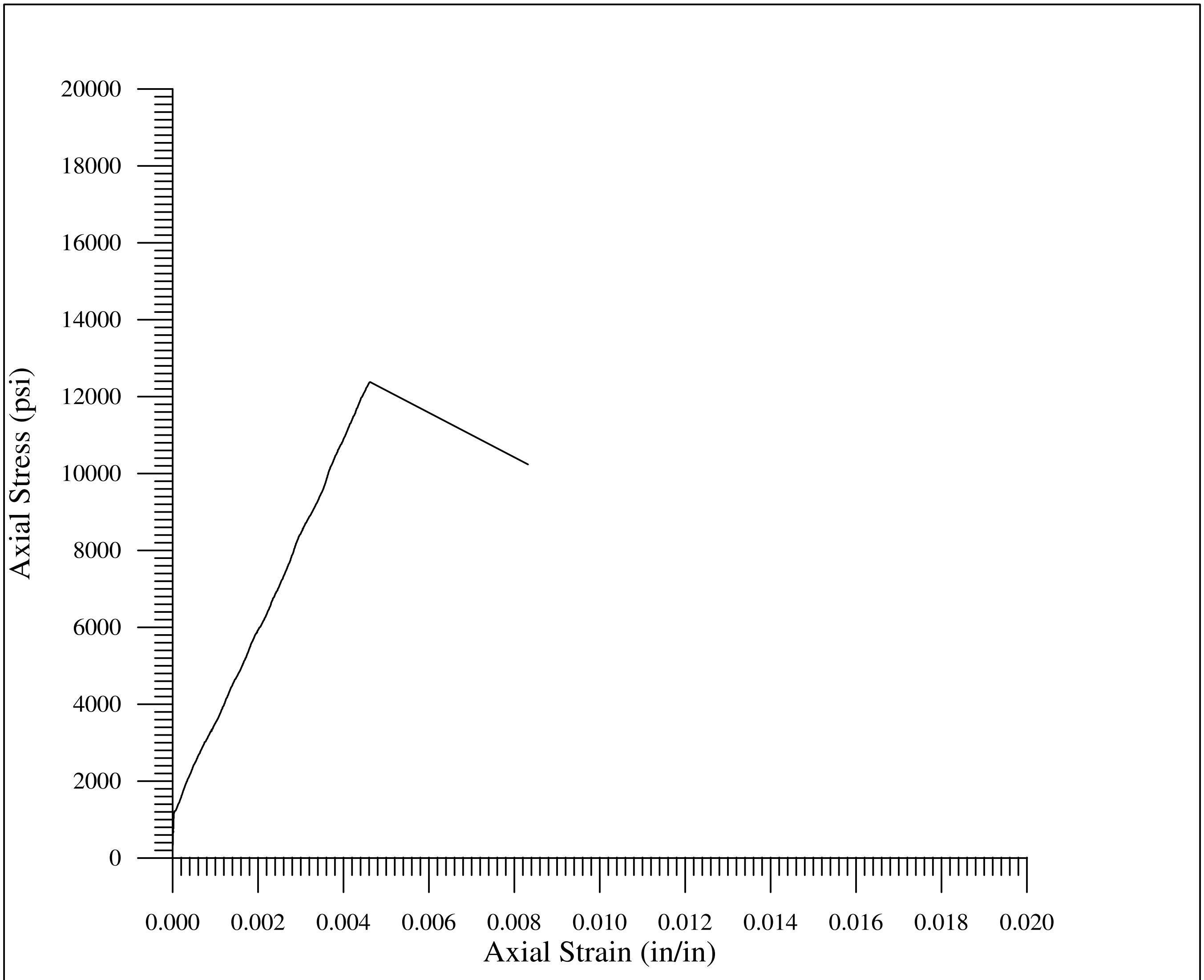

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 01-102B
Boring: RKS-01-07
Depth: 44.8-45.5'

DESCRIPTION

Dark gray meta-andesite with a healed calcite vein and calcite inclusions.

Density: 171.6 pcf
Strength: 12,380 psi

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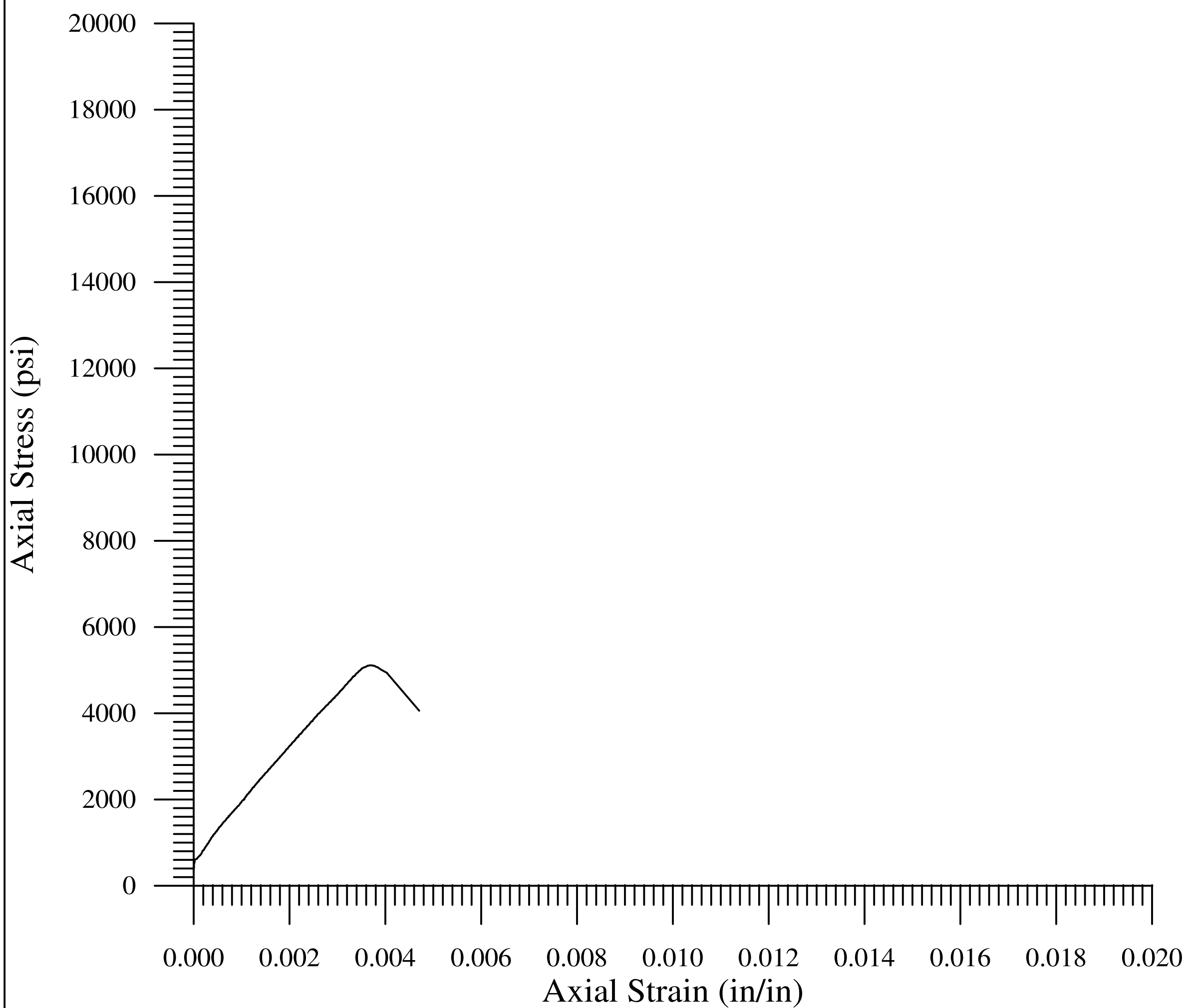
Project Number: 03-2007

Test Date: October 10, 2007



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 03-102B
Boring: RKS-03-07
Depth: 71.6-72.3'

DESCRIPTION

Dark gray fine grained and dark greenish gray medium grained meta-lapilli tuff.

Density: 165.1 pcf
Strength: 5113 psi

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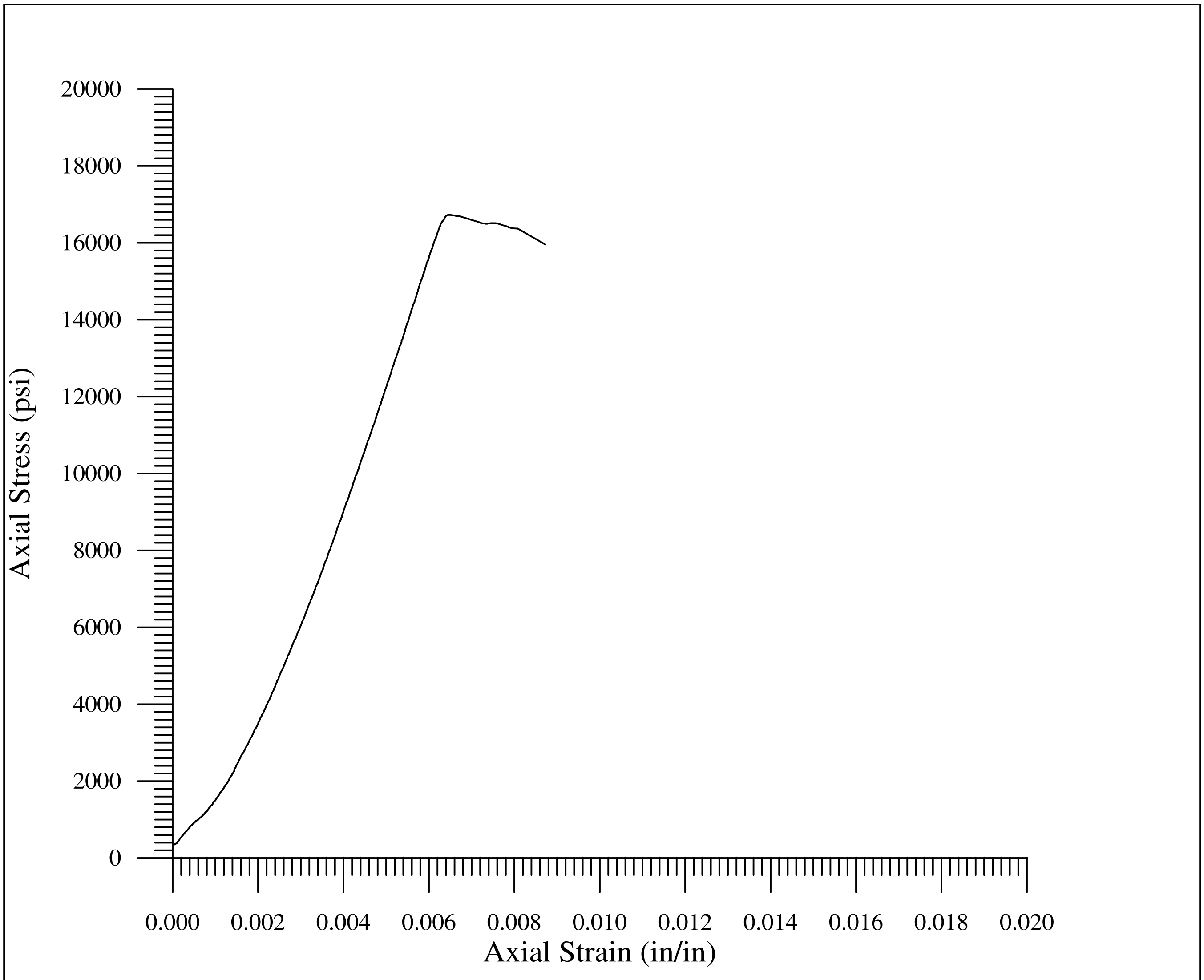
Project: I-90 Hyak Realignment

Project Number: 03-2007

Test Date: October 10, 2007



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 04-101B
Boring: RKS-04-07
Depth: 25.2-26.0'

DESCRIPTION

Medium gray meta-welded lapilli tuff with no apparent planes of weakness.

Density: 160.2 pcf
Strength: 16,725 psi

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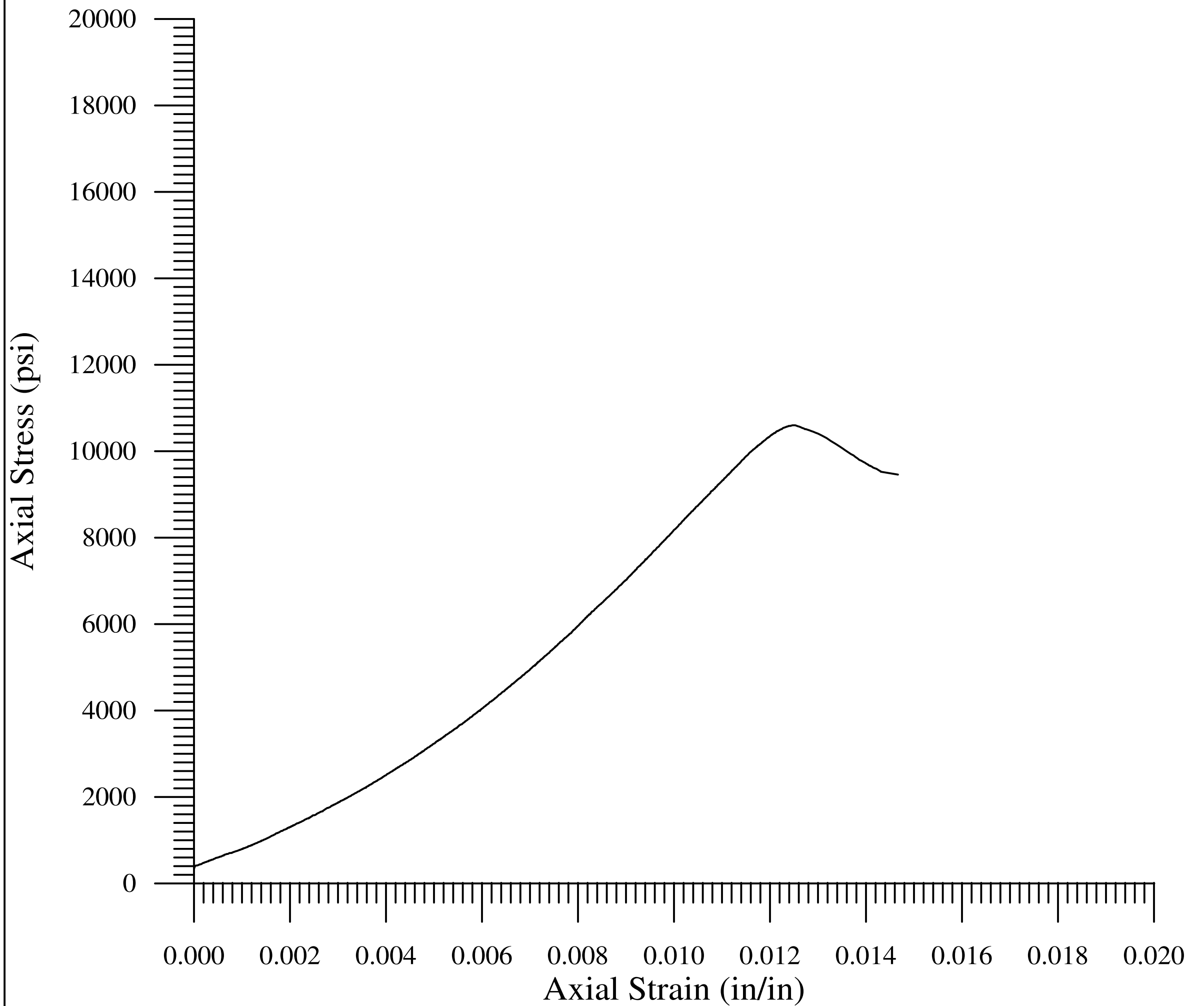

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 05-101B
Boring: RKS-05-07
Depth: 15.7-16.4'

DESCRIPTION

Dark purplish gray meta-basalt
with no apparent planes of weakness.

Density: 156.7 pcf
Strength: 10,599 psi

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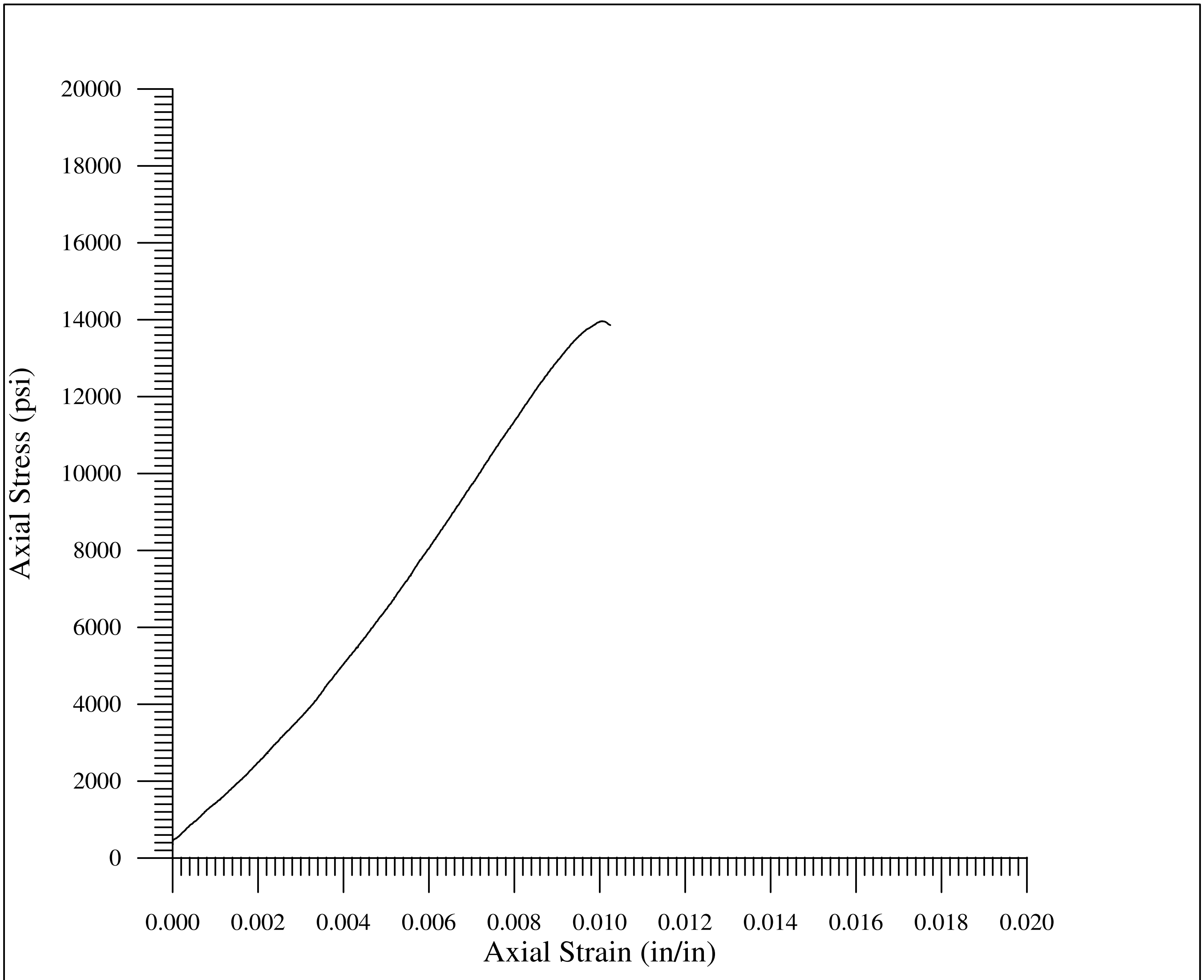
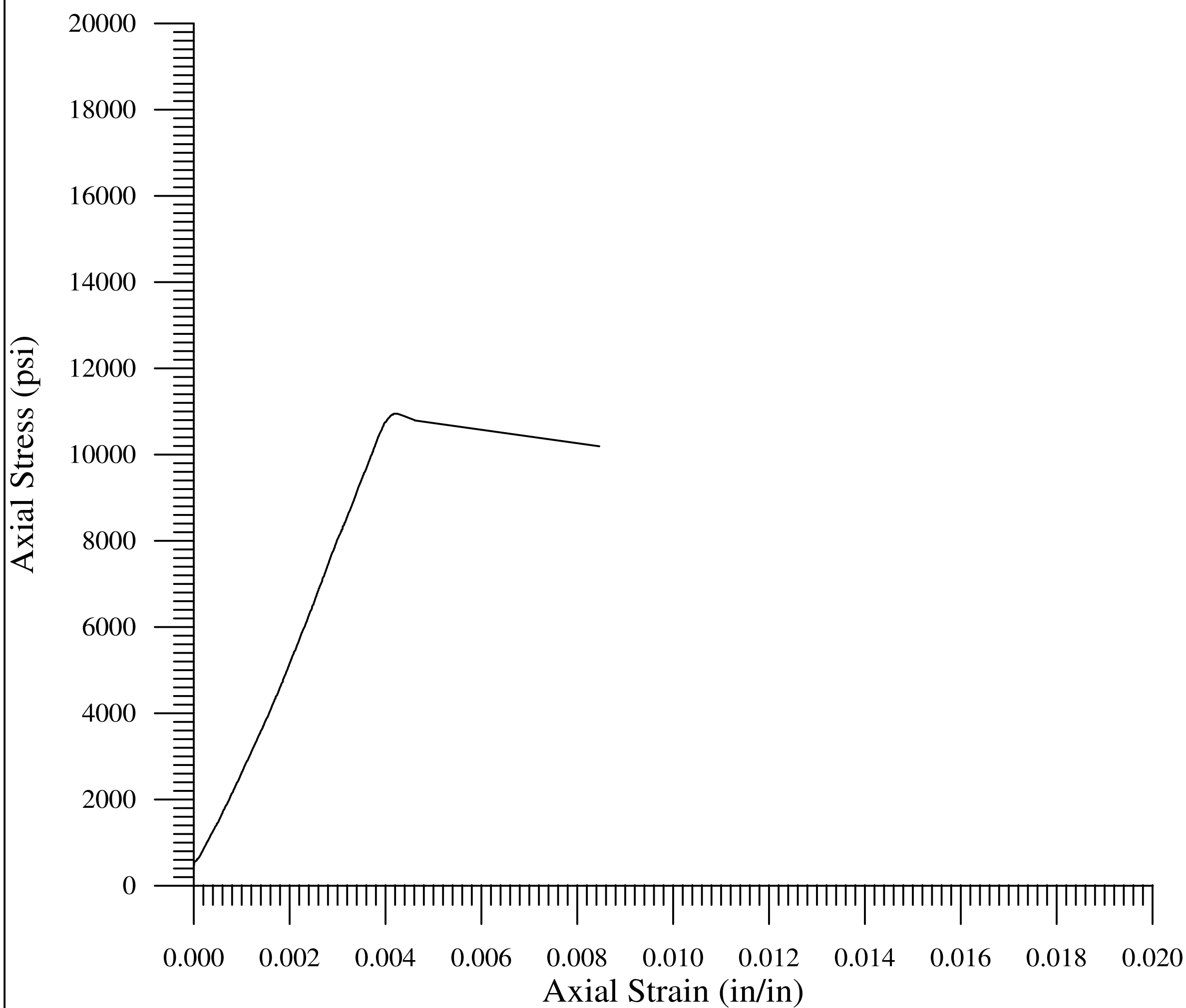


UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 05-103A **Boring: RKS-05-07** **Depth: 59.5-60.1'**	**Geo Test Unlimited** (GTU) **27069 N. Bloomfield Rd.** **Nevada City, CA 95959**
DESCRIPTION Dark purplish gray and dark greenish gray breciated andesite with no apparent planes of weakness.	**Client: Wyllie & Norrish Engineers** **17918 NE 27th St.** **Redmond, WA 98052**
Density: 165.6 pcf **Strength: 13,961 psi**	**Project: I-90 Hyak Realignment** **Project Number: 03-2007**
	Test Date: October 10, 2007



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 06-101A
Boring: RKS-06-07
Depth: 35.1-35.8'

DESCRIPTION

Dark gray meta-andesite with
quartz healed fractures and tight fractures.

Density: 174.6 pcf
Strength: 10,946 psi

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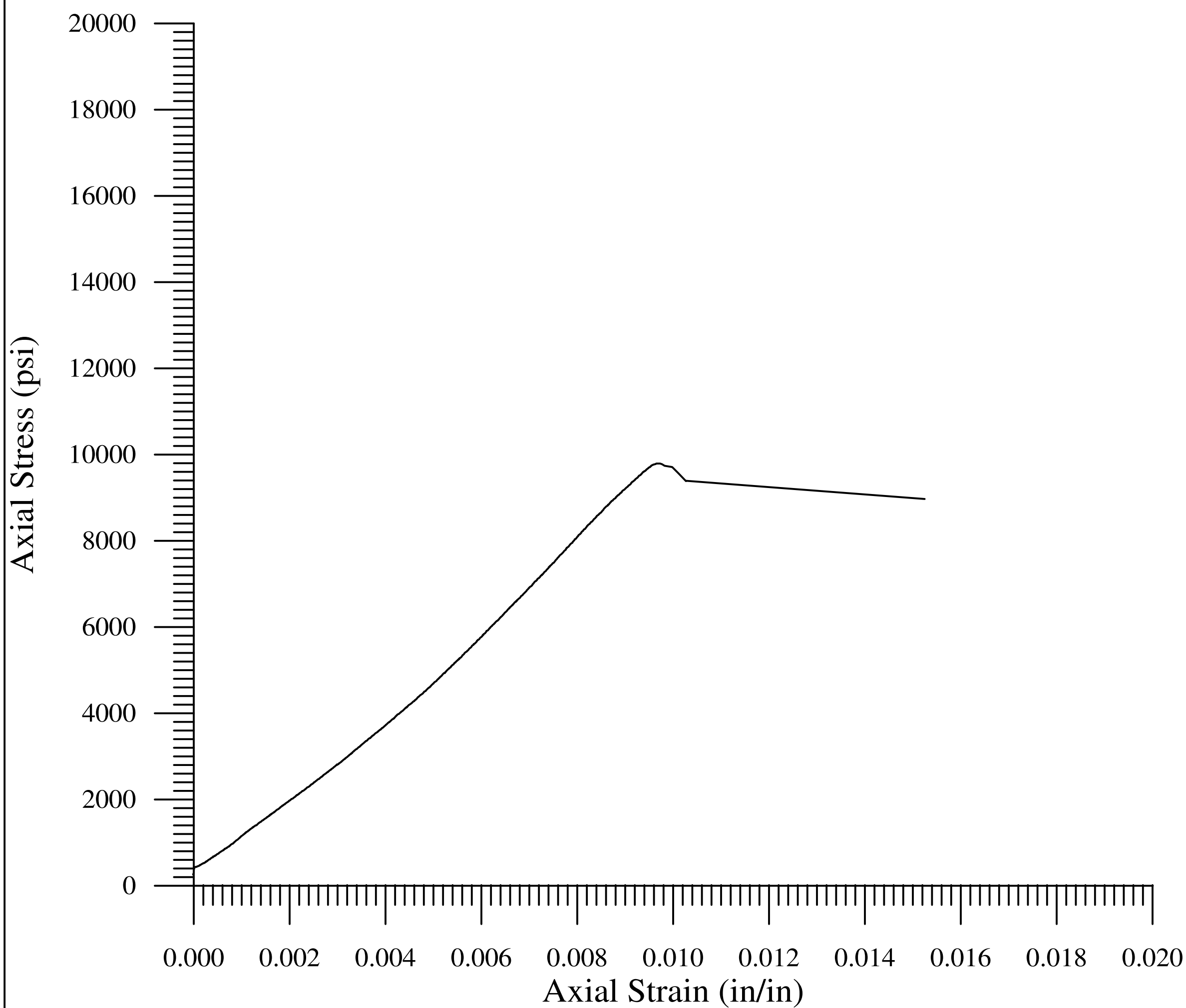

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 08-101A
Boring: RKS-08-07
Depth: 10.0-10.7'

DESCRIPTION

Medium gray meta-welded lapilli tuff with no apparent planes of weakness.

Density: 158.1 pcf
Strength: 9795 psi

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Project Number: 03-2007

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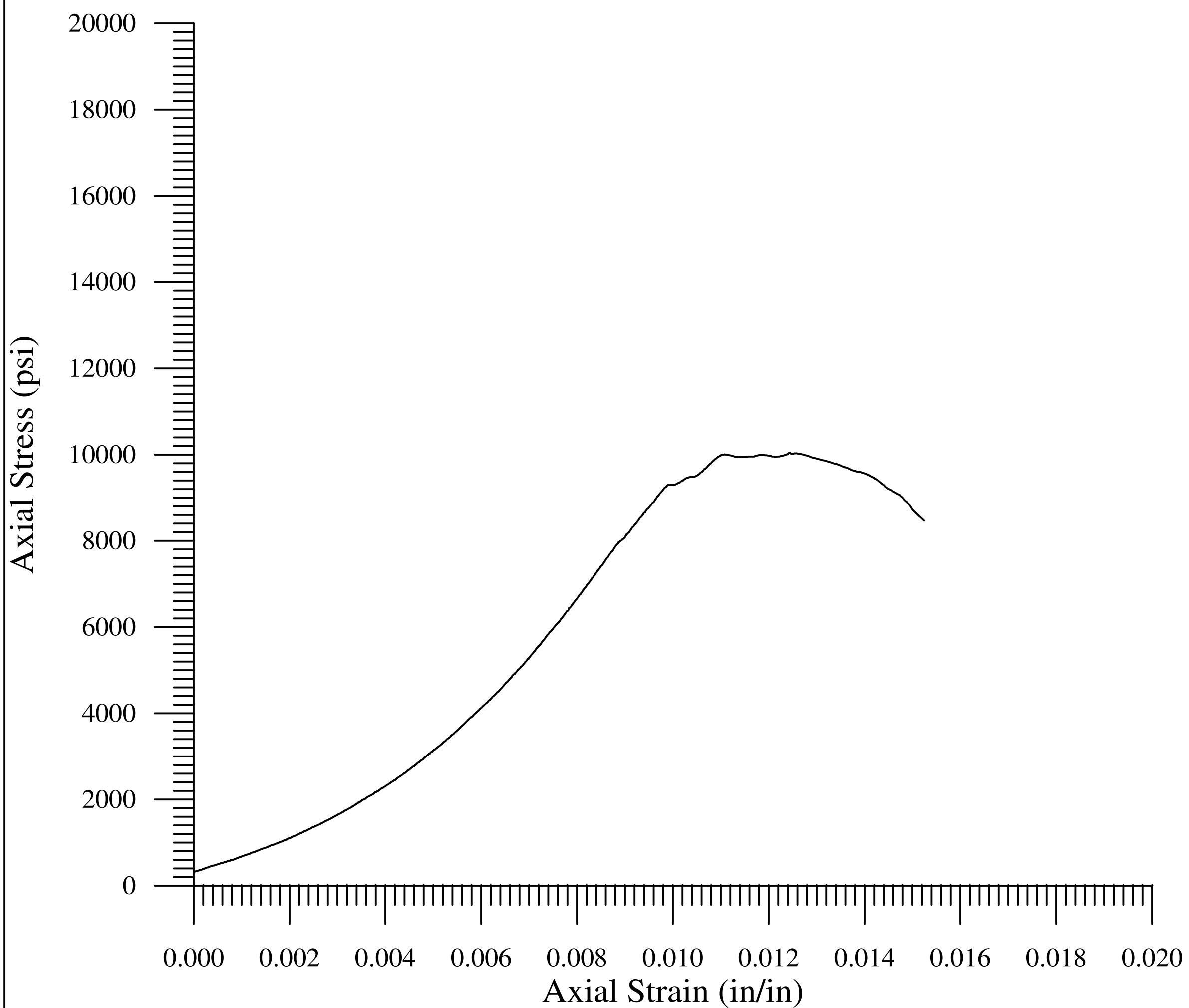

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 09-102B
Boring: RKS-09-07
Depth: 41.9-42.6'

DESCRIPTION

Medium gray meta-welded lapilli tuff with no apparent planes of weakness.

Density: 156.6 pcf
Strength: 10,040 psi

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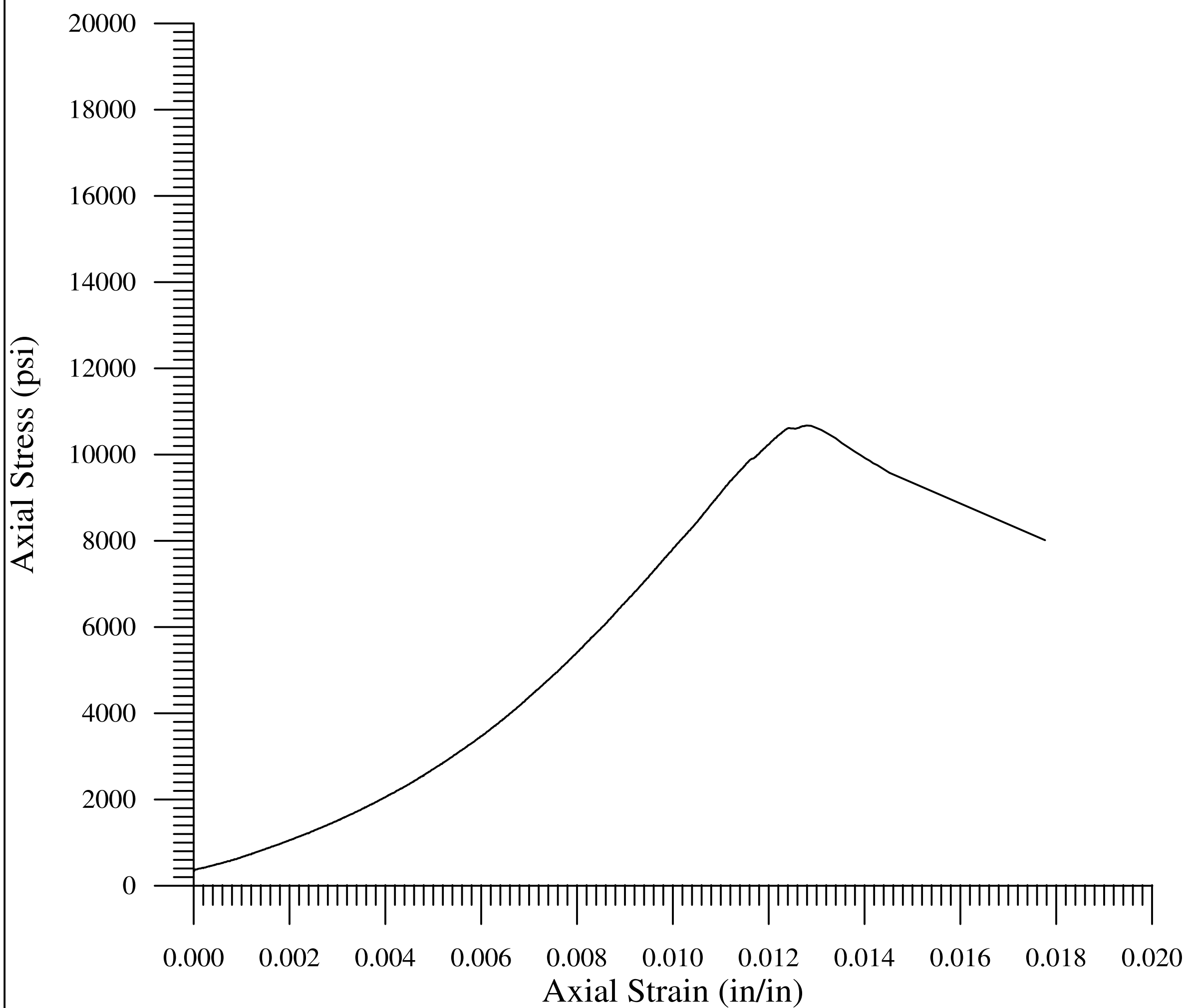

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 10-2A
Boring: RKS-10-07
Depth: 74.1-74.8'

DESCRIPTION

Medium gray meta-welded lapilli tuff with no apparent planes of weakness.

Density: 154.6 pcf
Strength: 10,674 psi

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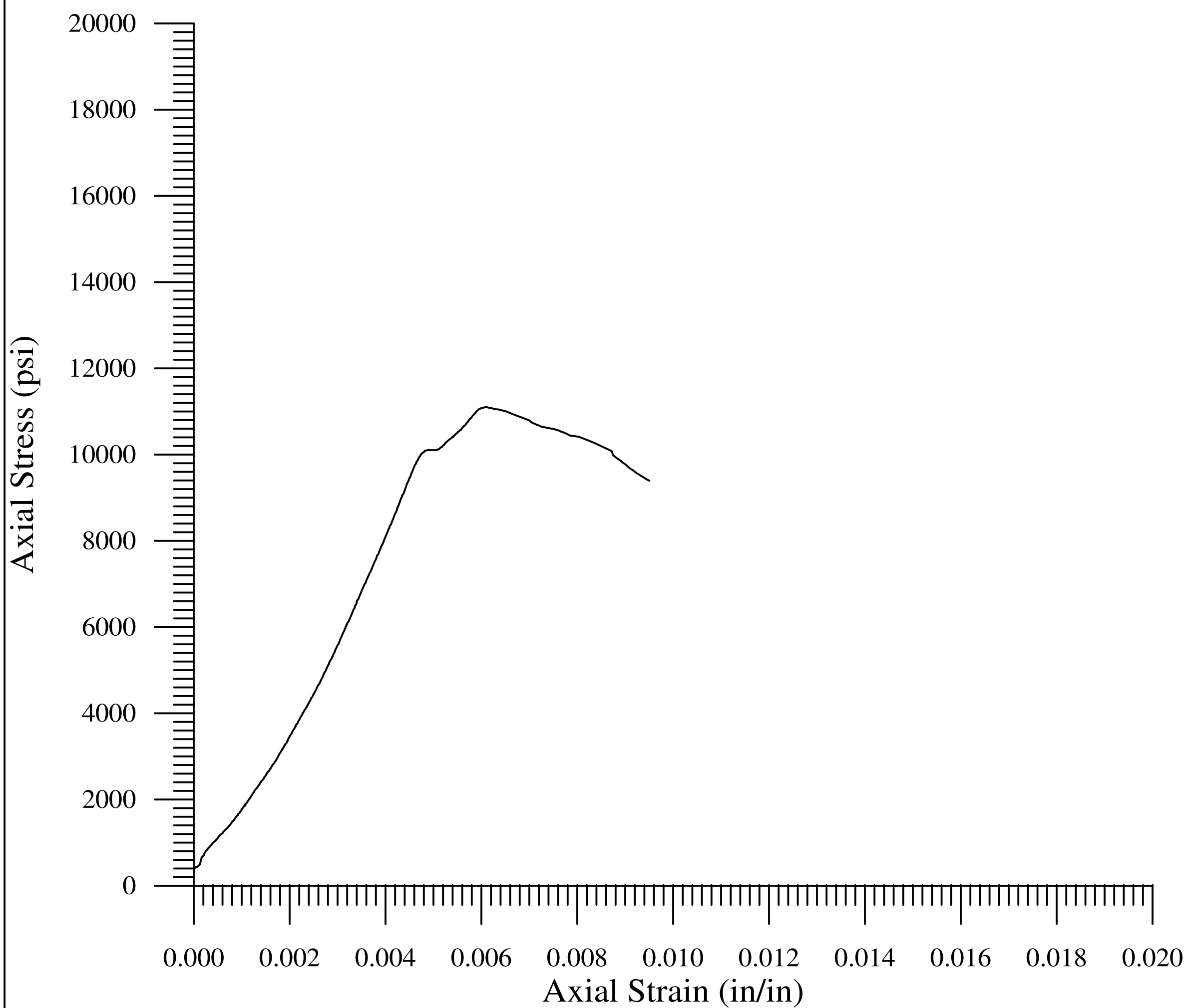
Project Number: 03-2007

Test Date: October 10, 2007



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 11-101A
Boring: RKS-11-07
Depth: 64.1-64.8'

DESCRIPTION

Medium gray meta-welded lapilli tuff with a few tight fractures.

Density: 161.3 pcf
Strength: 11,100 psi

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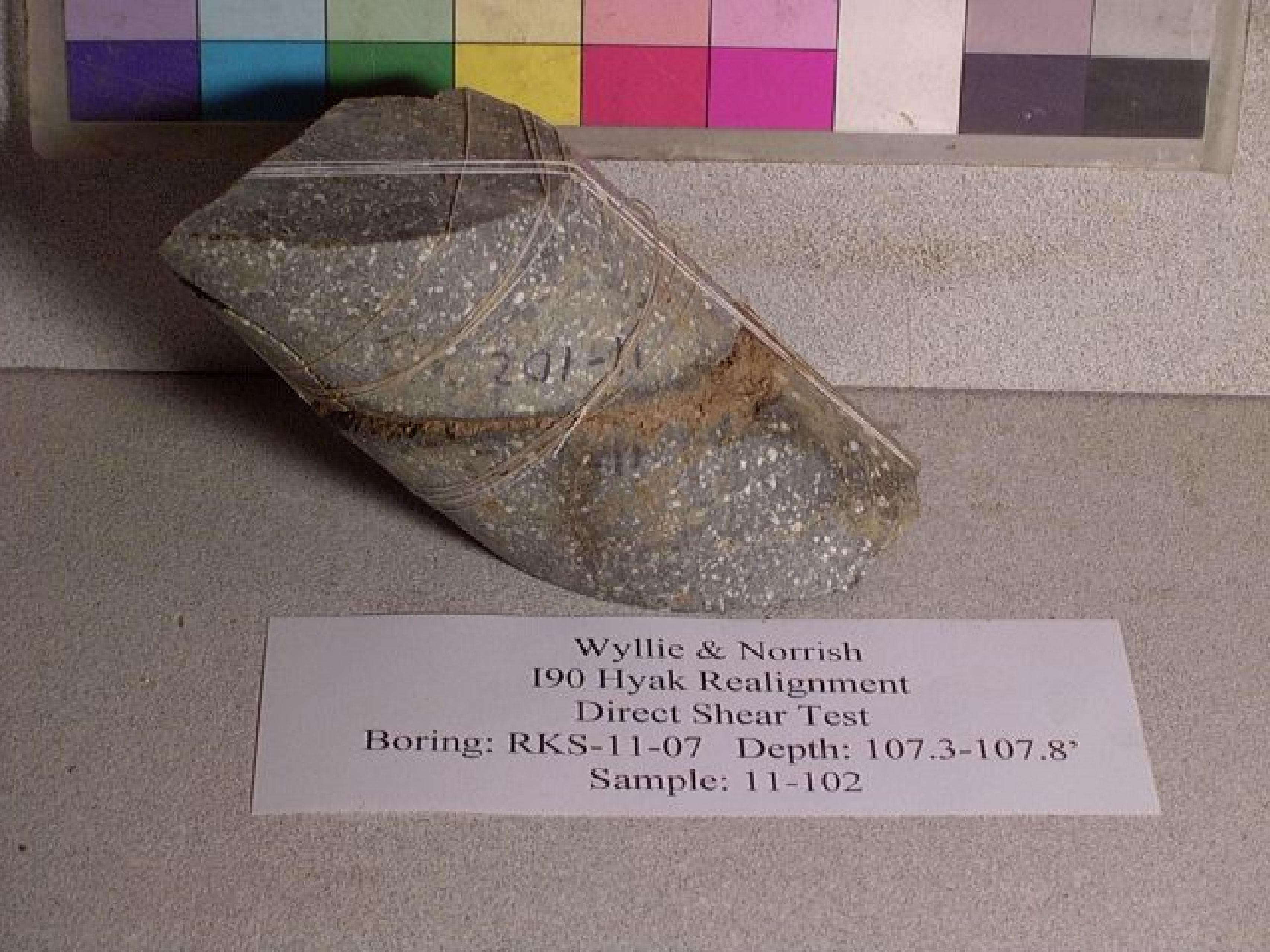
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I90 Hyak Realignment
Direct Shear Test
Boring: RKS-11-07   Depth: 107.3-107.8'
Sample: 11-102


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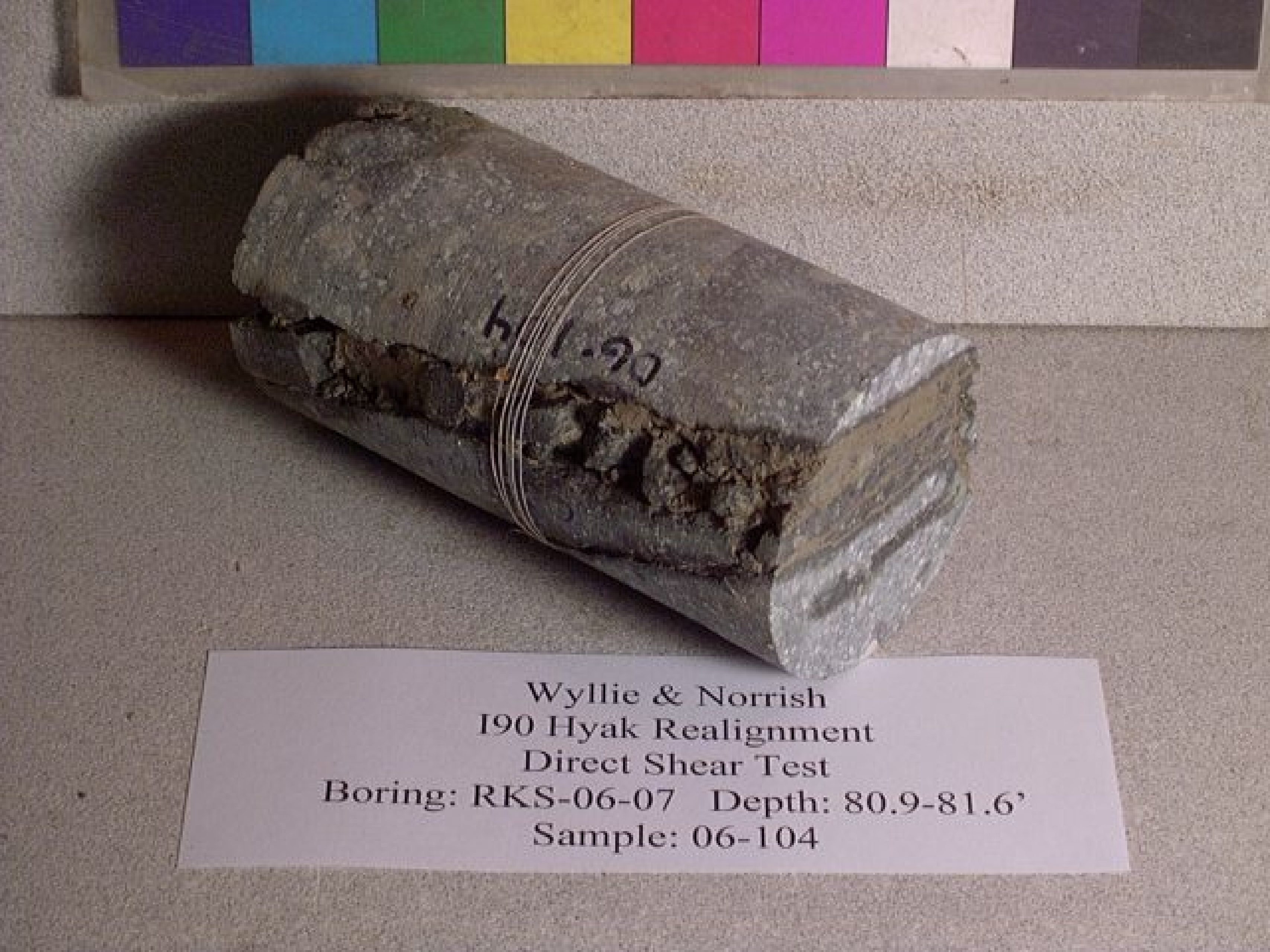
I90 Hyak Realignment
Direct Shear Test
Boring: RKS-11-07 Depth: 107.3-107.8'
Sample: 11-102


Wyllie & Norrish
I90 Hyak Realignment
Direct Shear Test
Boring: RKS-06-07 Depth: 80.9-81.6'
Sample: 06-104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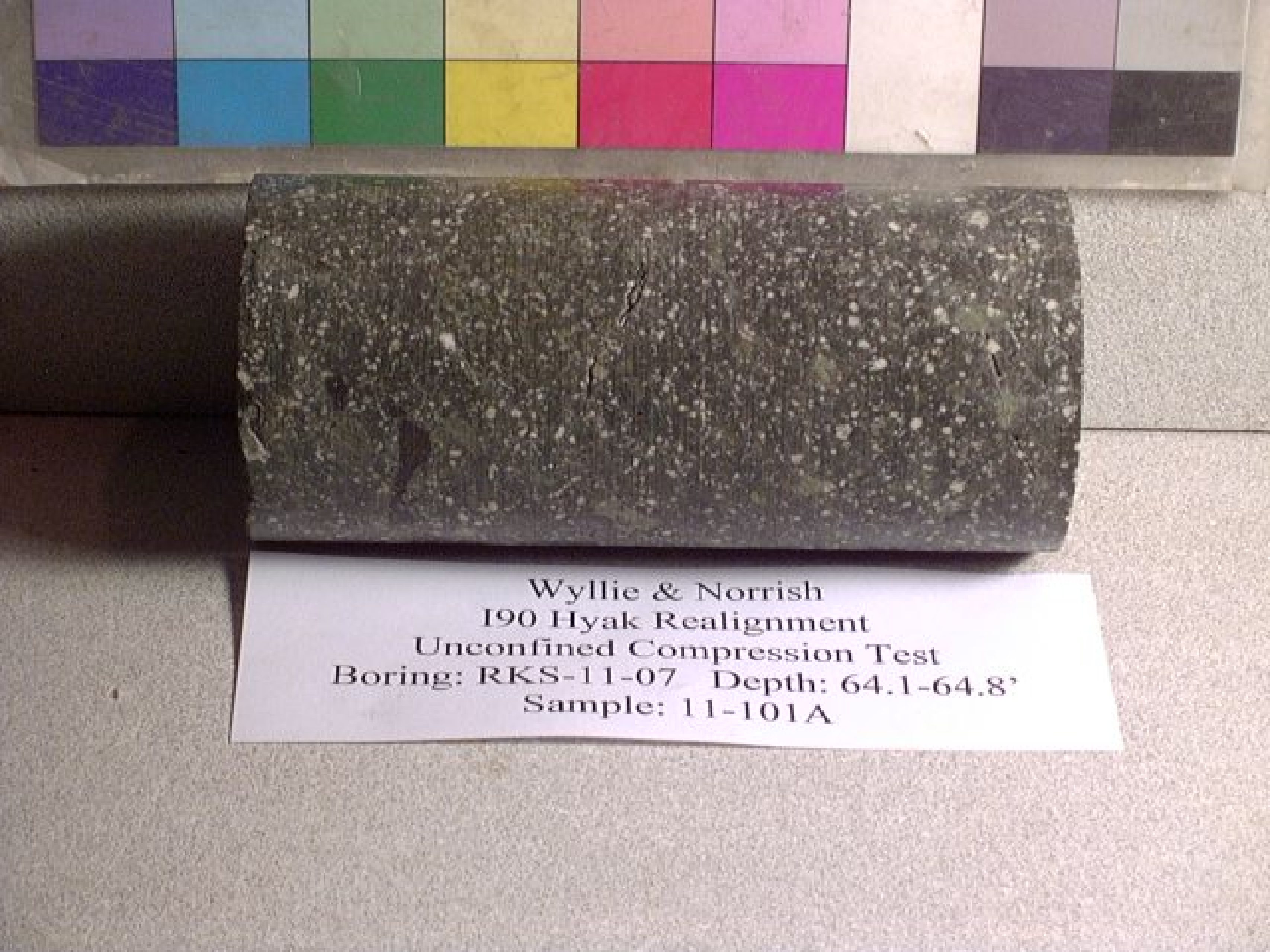
Direct Shear Test
Boring: RKS-06-07 Depth: 80.9-81.6'
Sample: 06-104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I90 Hyak Realignment
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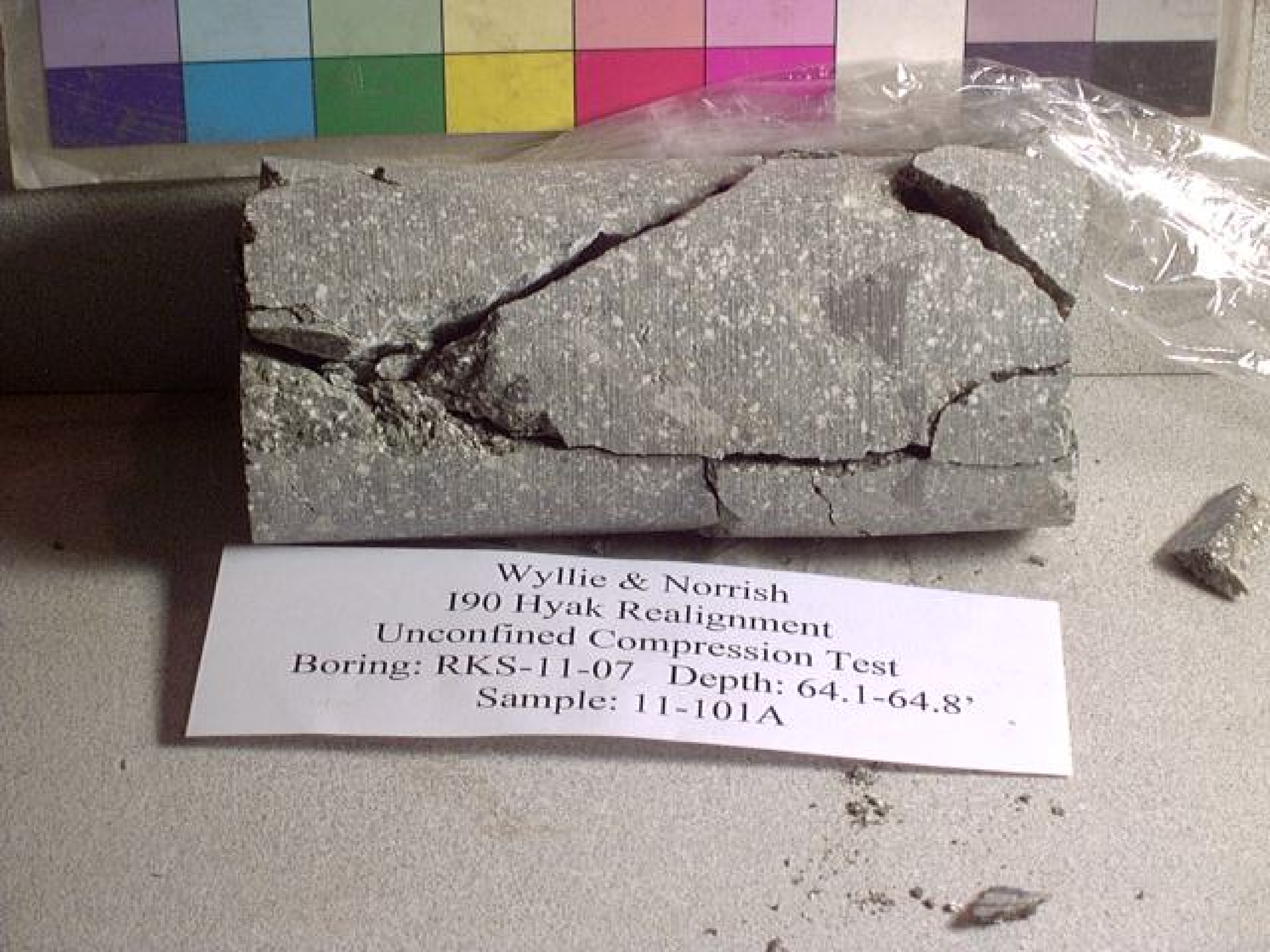
Boring: RKS-11-07 Depth: 64.1-64.8'
Sample: 11-101A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190 Hyak Realignment
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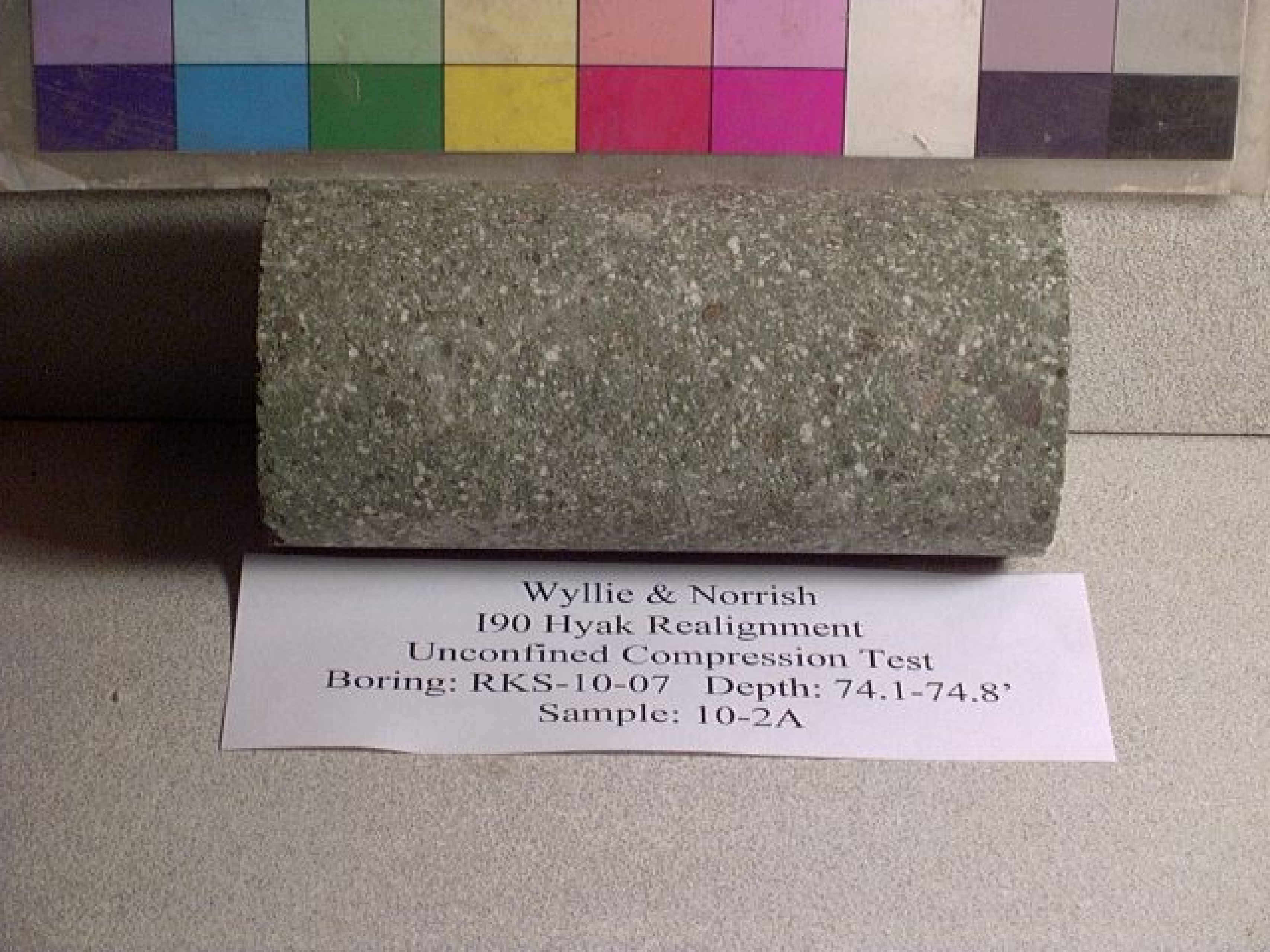
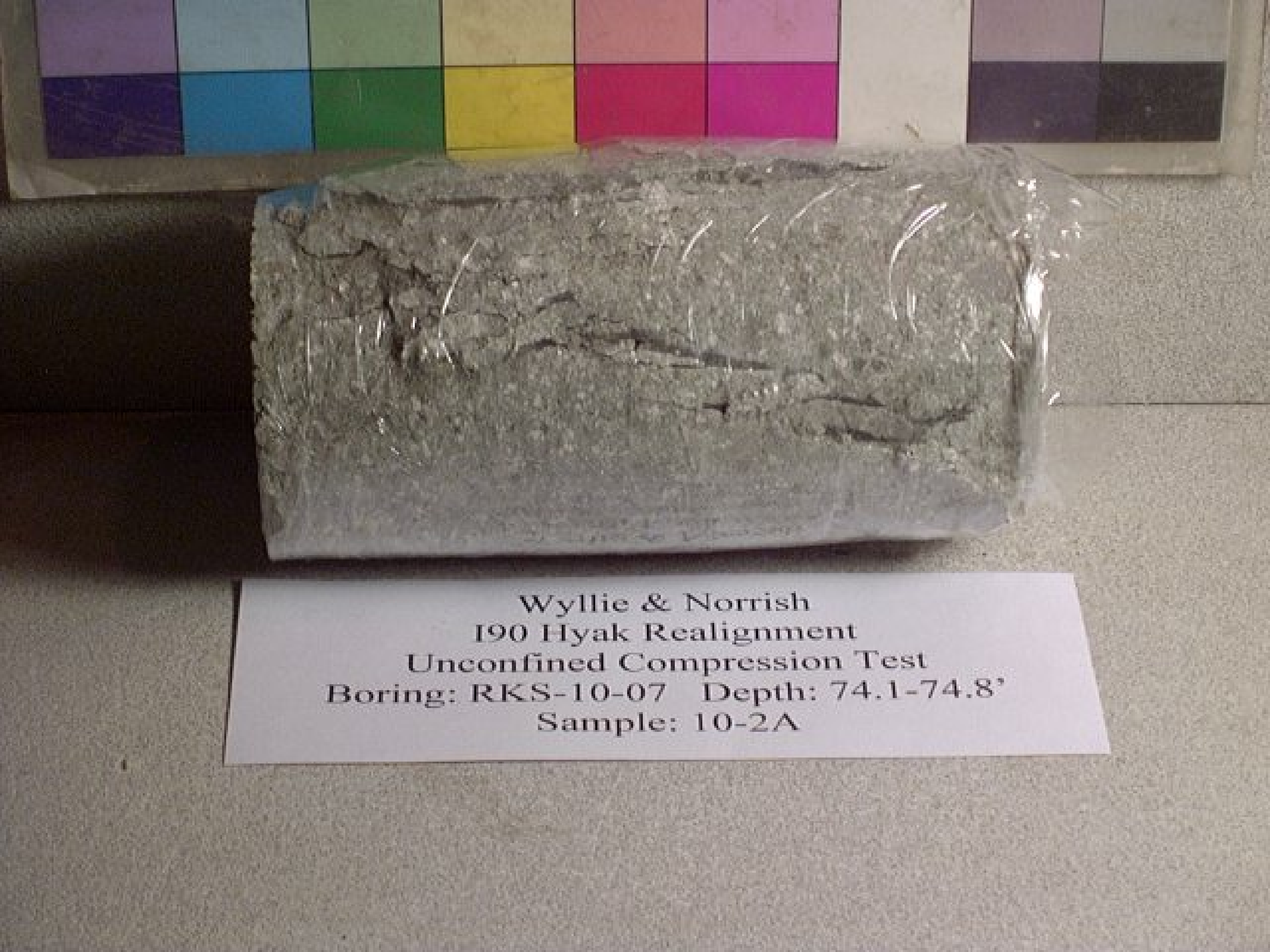
Boring: RKS-11-07 Depth: 64.1-64.8'
Sample: 11-101A


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-10-07 Depth: 74.1-74.8'
Sample: 10-2A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I90 Hyak Realignment
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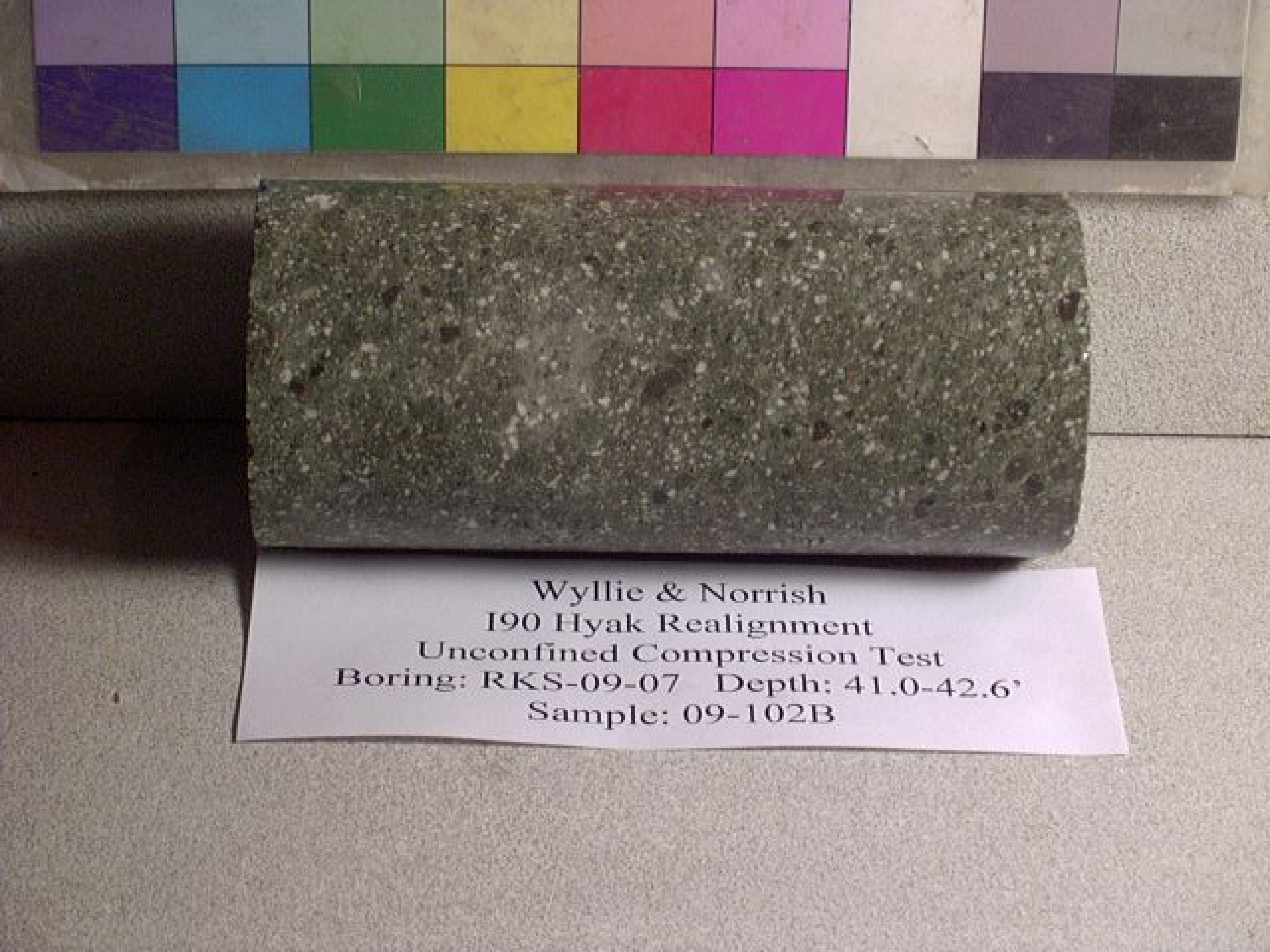
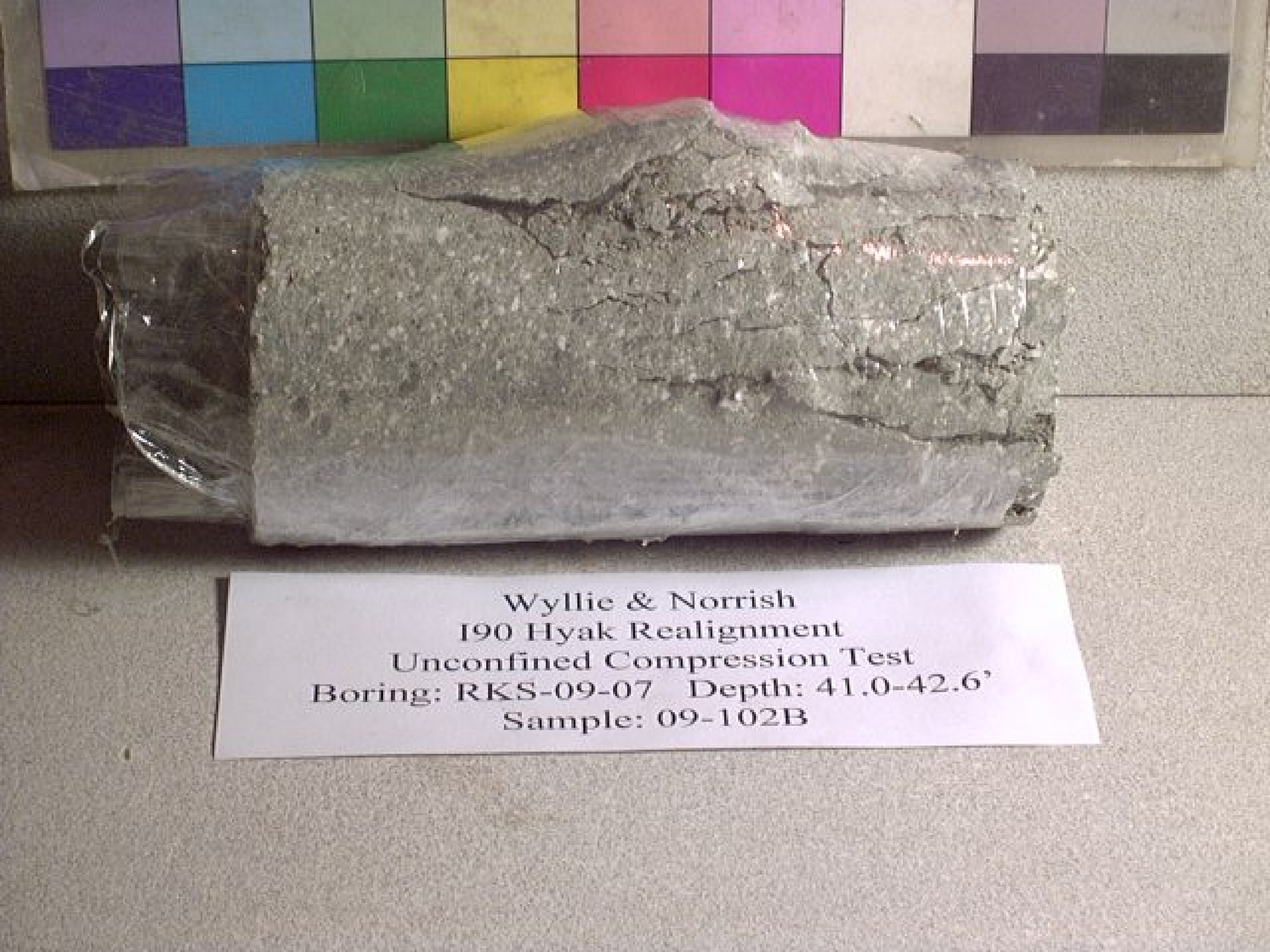
Sample: 10-2A



Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-09-07 Depth: 41.0-42.6'
Sample: 09-102B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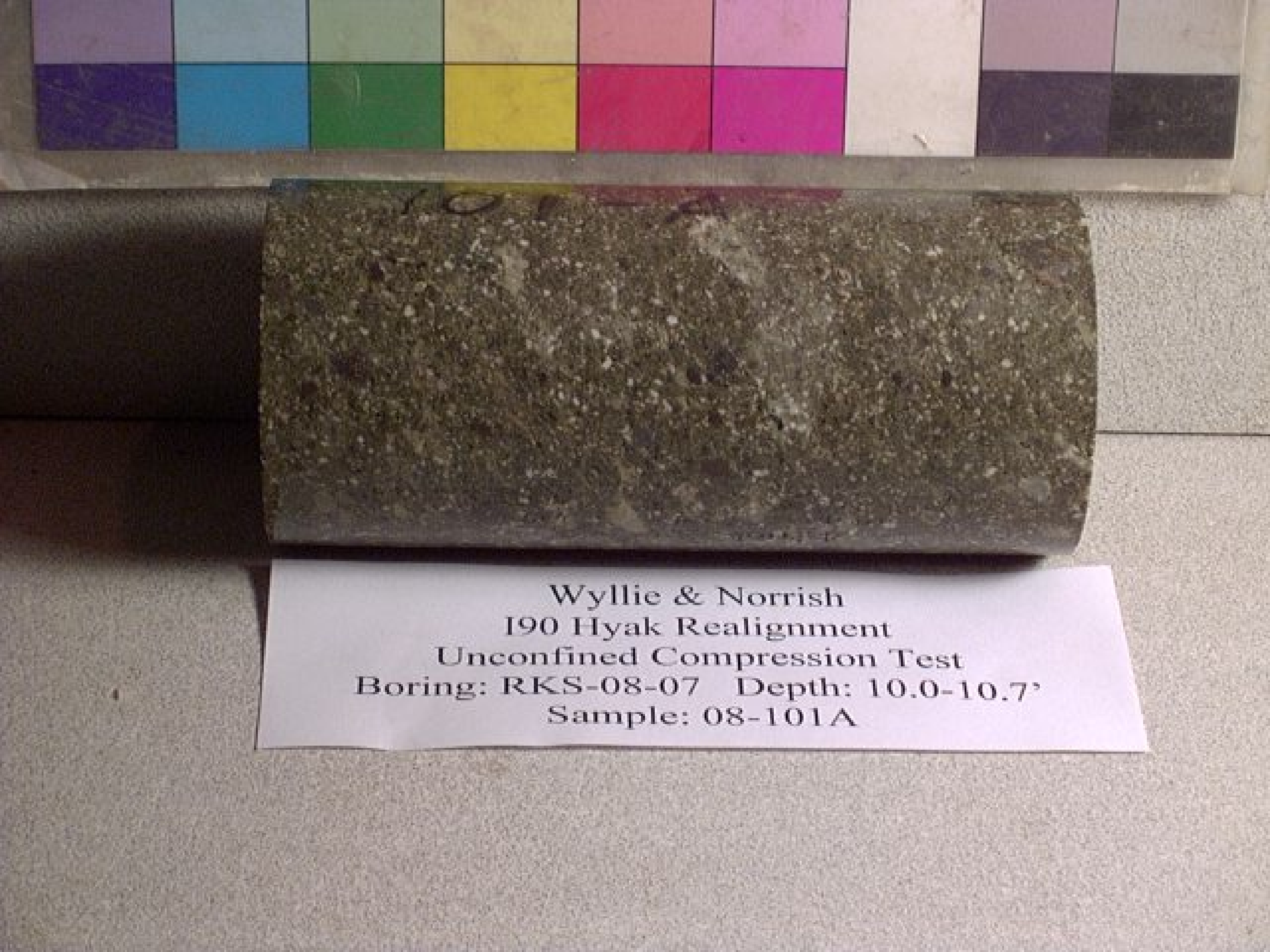
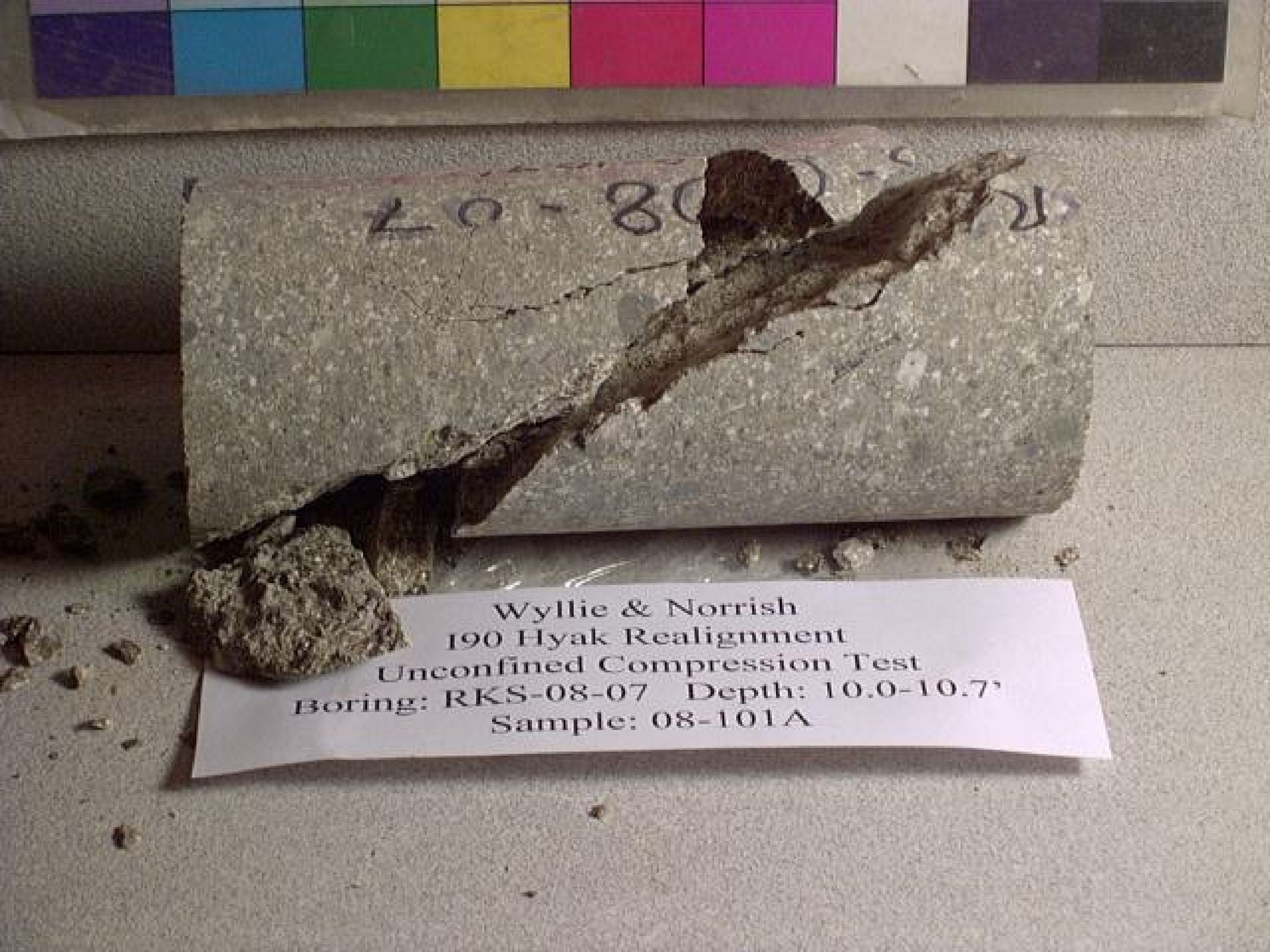
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-09-07 Depth: 41.0-42.6'
Sample: 09-102B


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-08-07 Depth: 10.0-10.7'
Sample: 08-101A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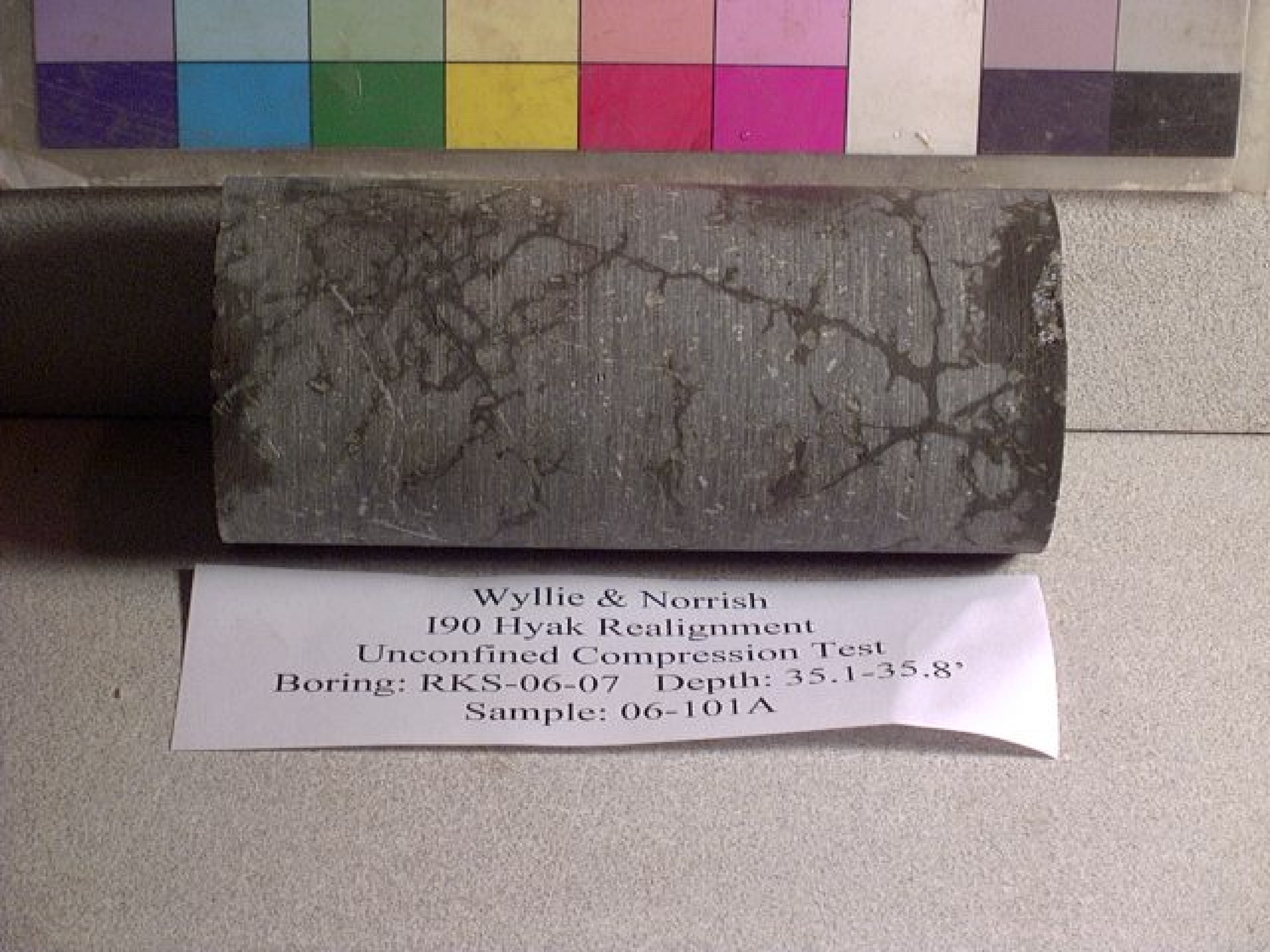
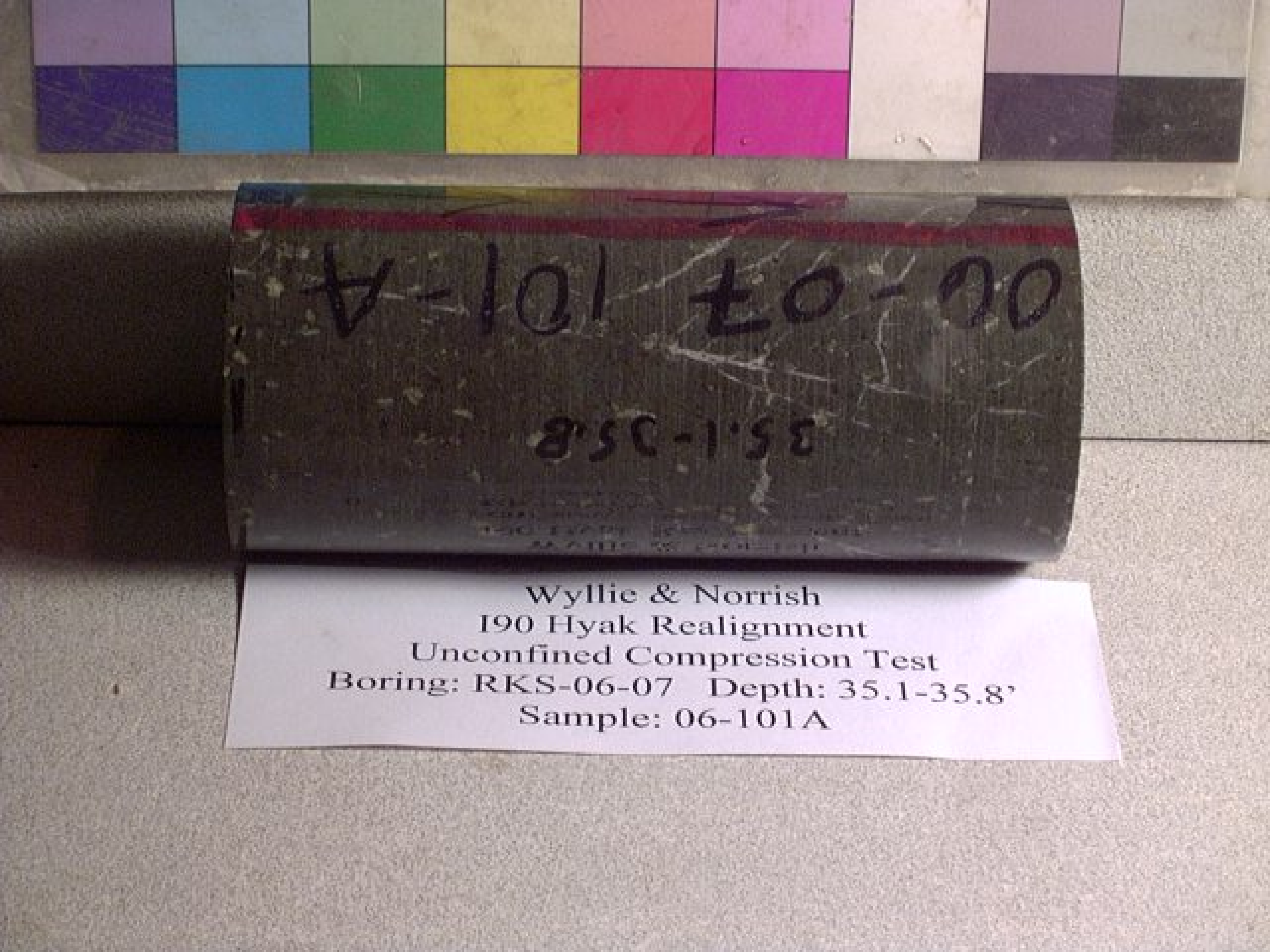
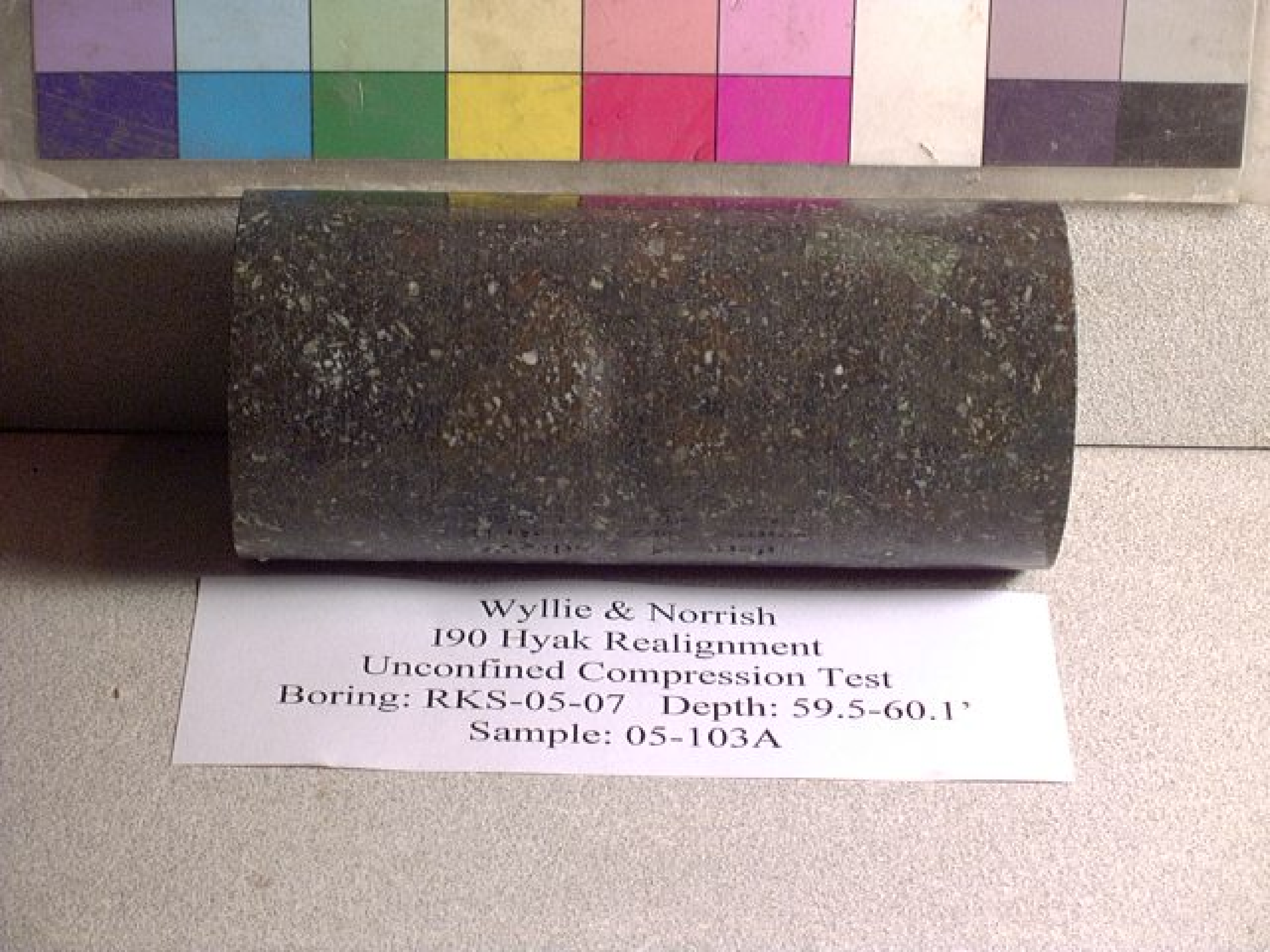
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-08-07 Depth: 10.0-10.7'
Sample: 08-101A


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-06-07 Depth: 35.1-35.8'
Sample: 06-101A


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-06-07   Depth: 35.1-35.8'
Sample: 06-101A


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-06-07 Depth: 35.1-35.8'
Sample: 06-101A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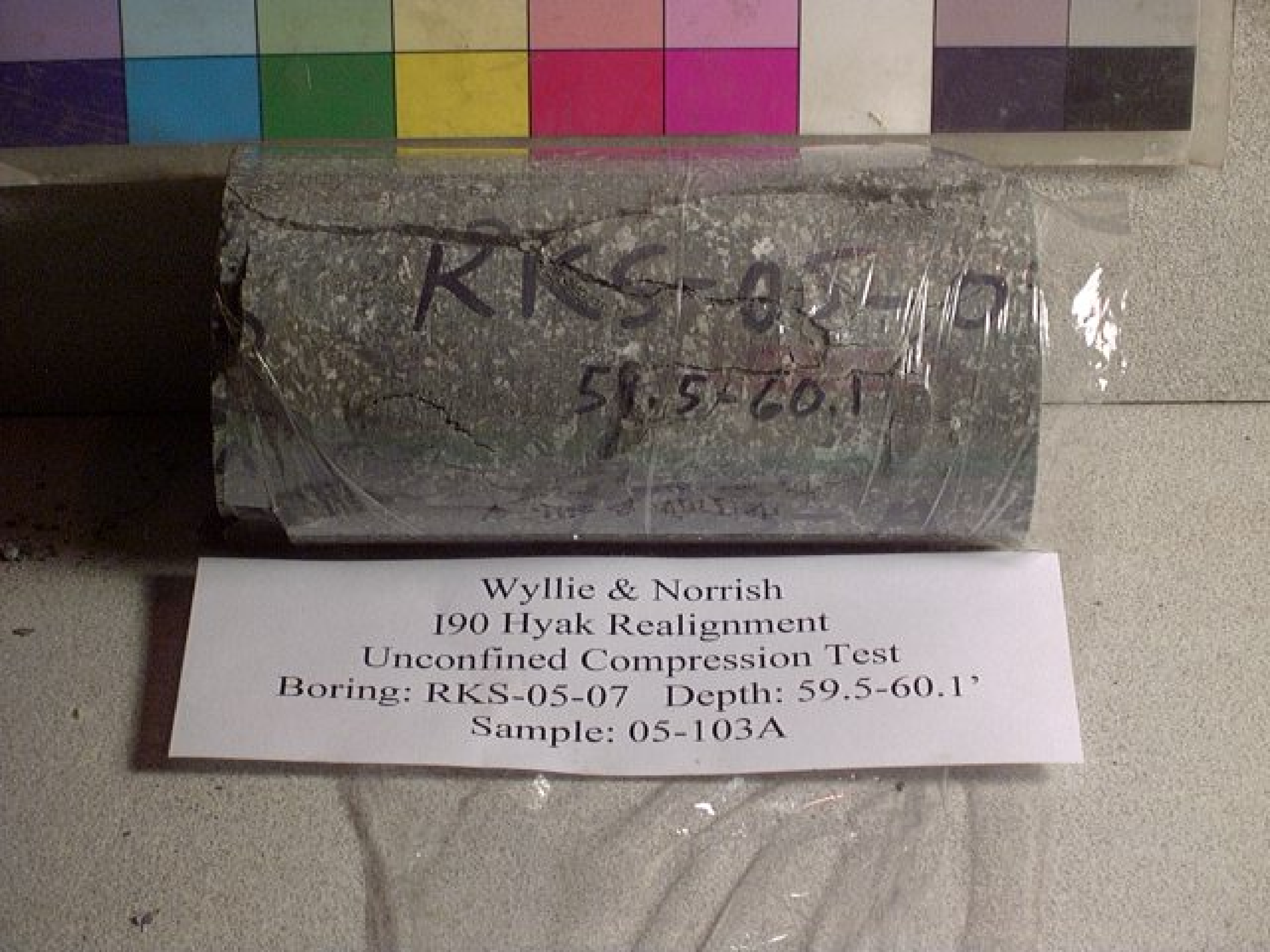
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-05-07 Depth: 59.5-60.1'
Sample: 05-103A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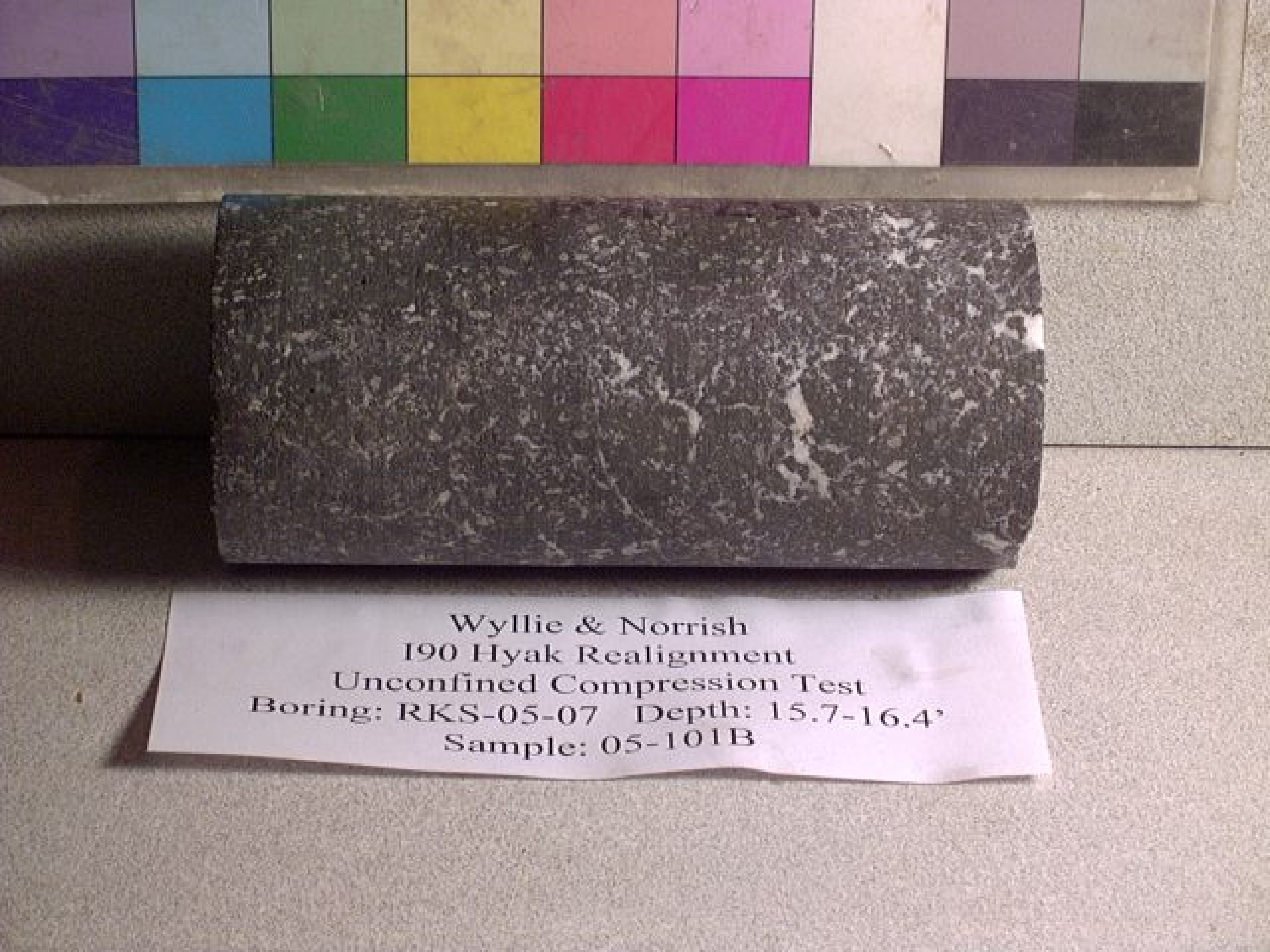
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-05-07   Depth: 59.5-60.1'
Sample: 05-103A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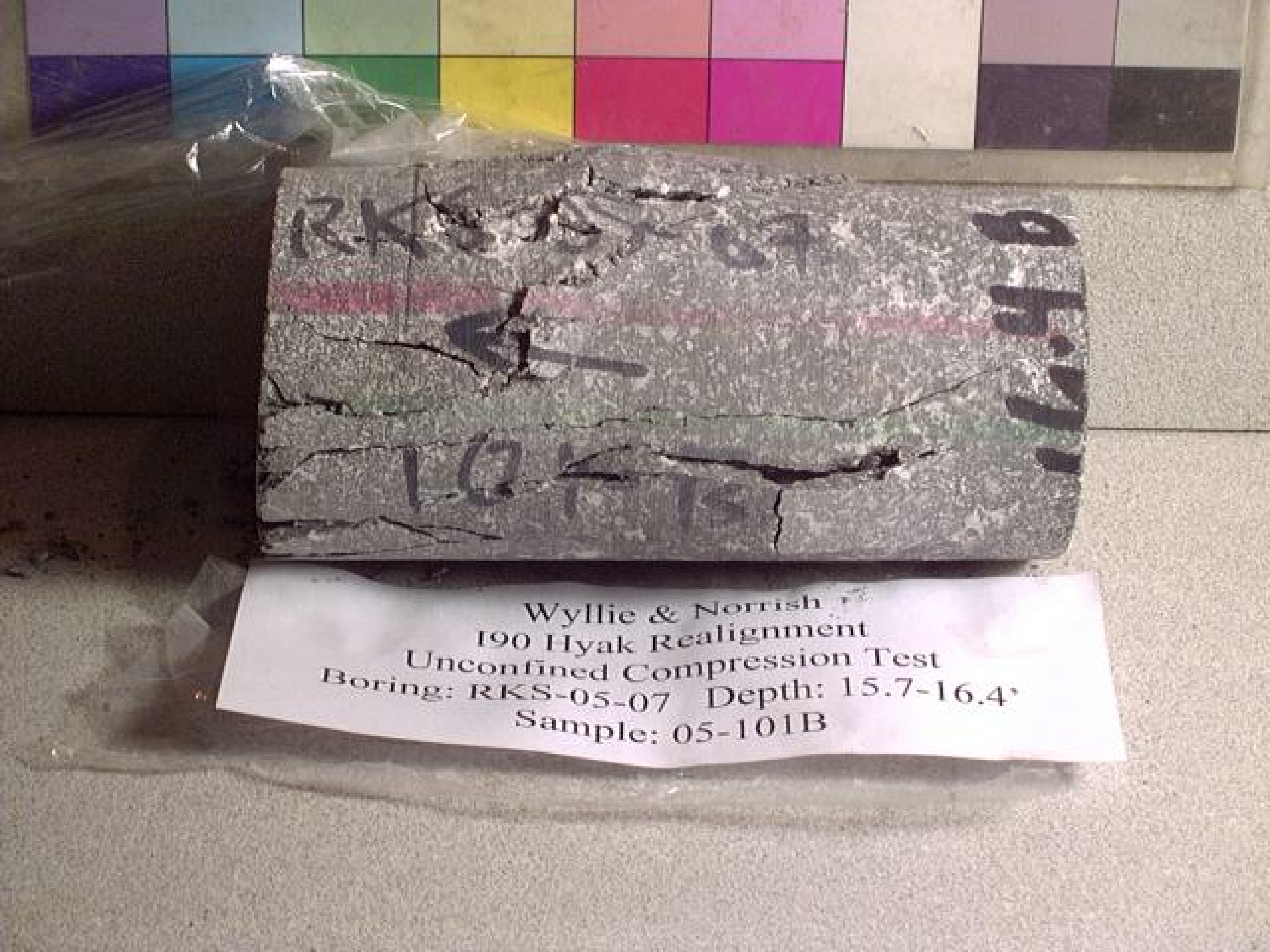
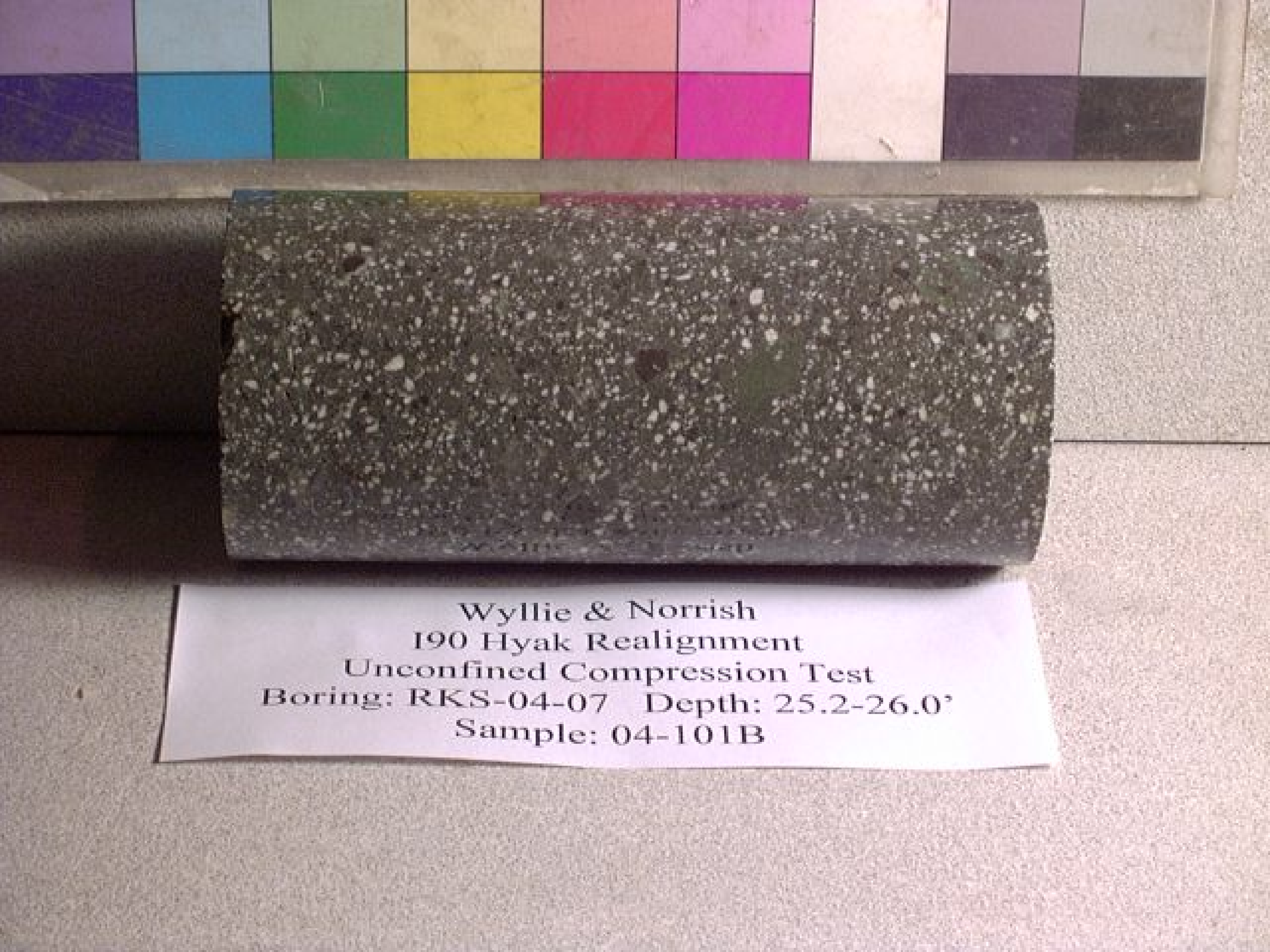
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-05-07 Depth: 15.7-16.4'
Sample: 05-101B


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-05-07 Depth: 15.7-16.4'
Sample: 05-101B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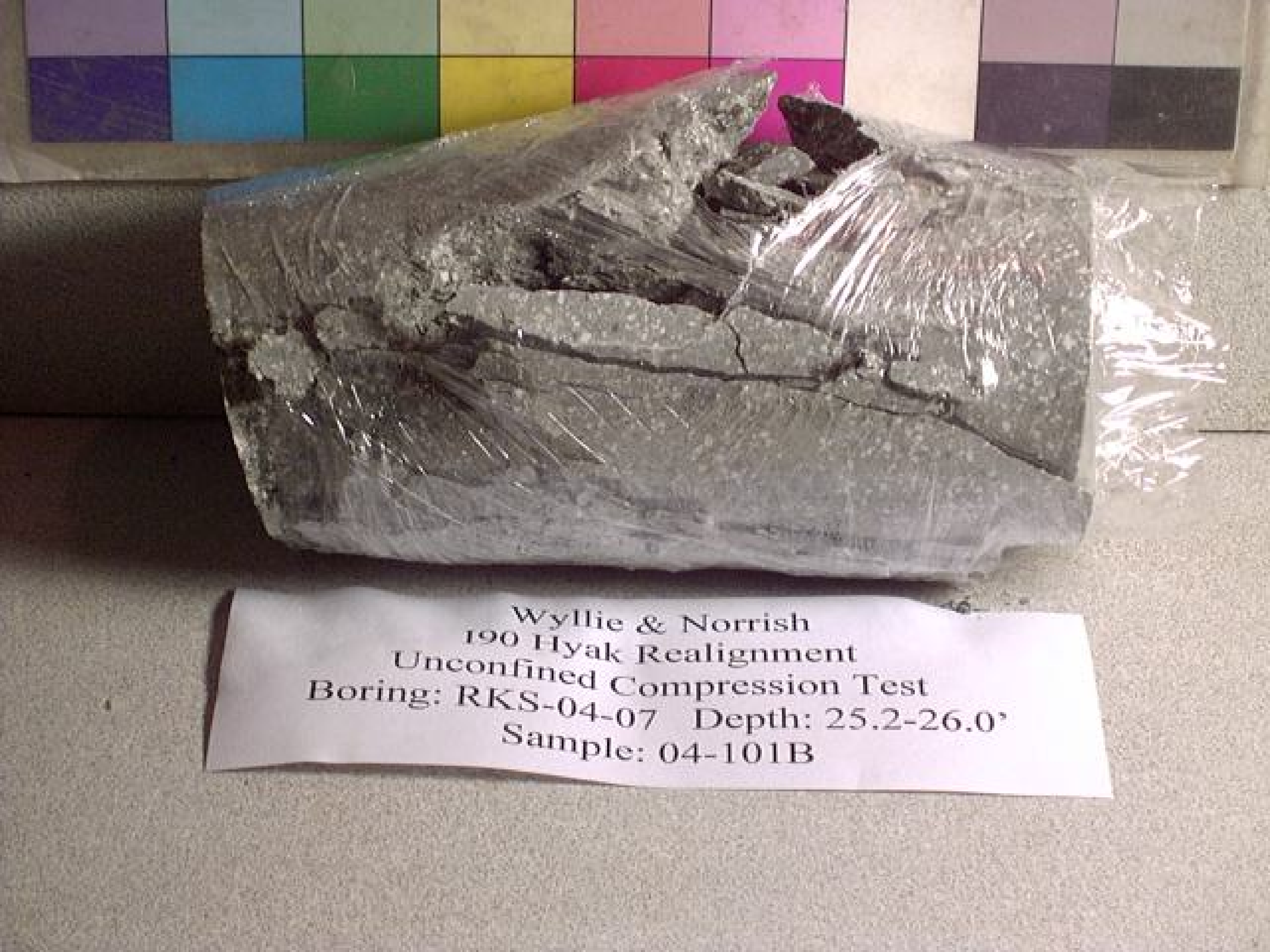
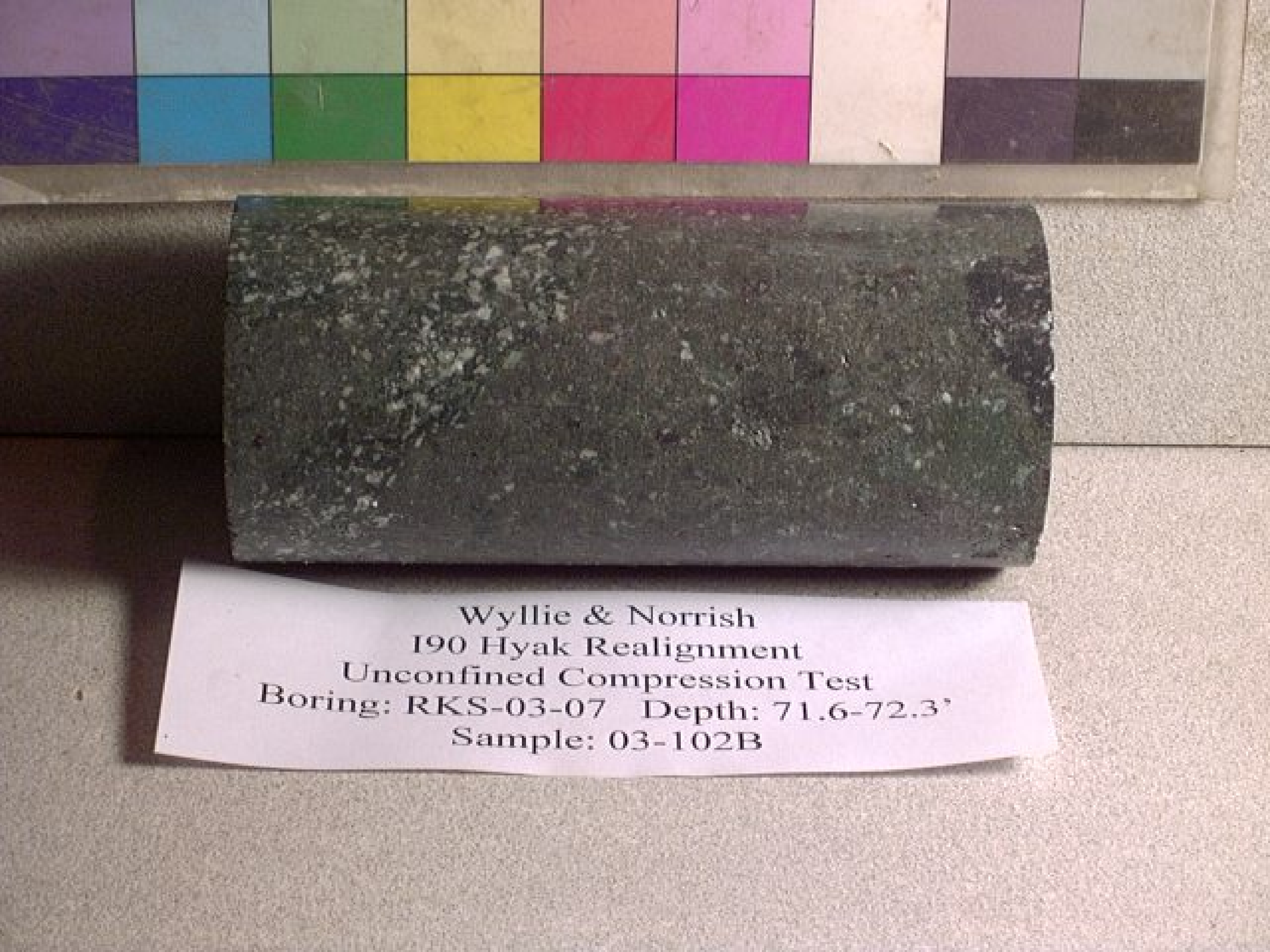
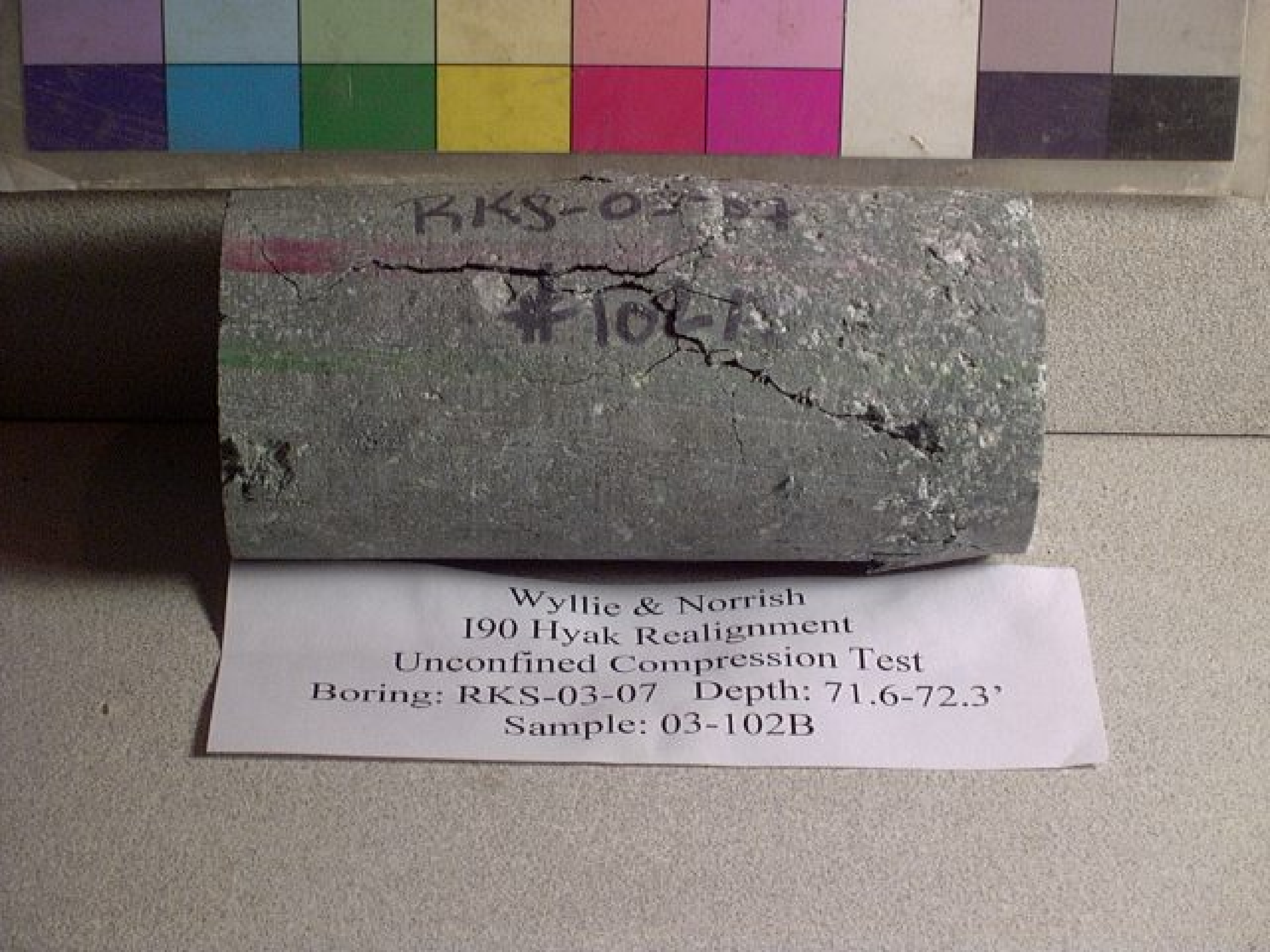
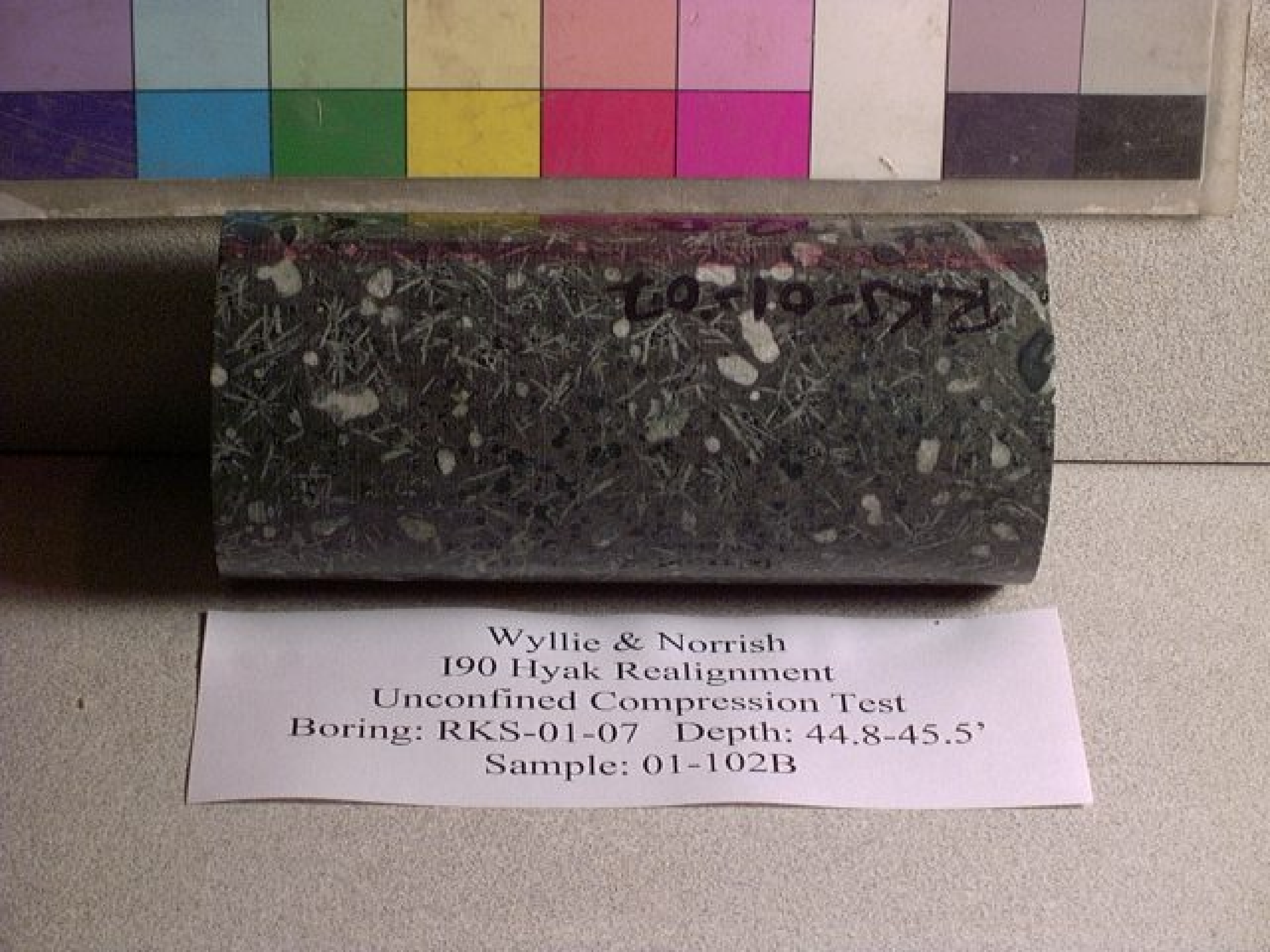
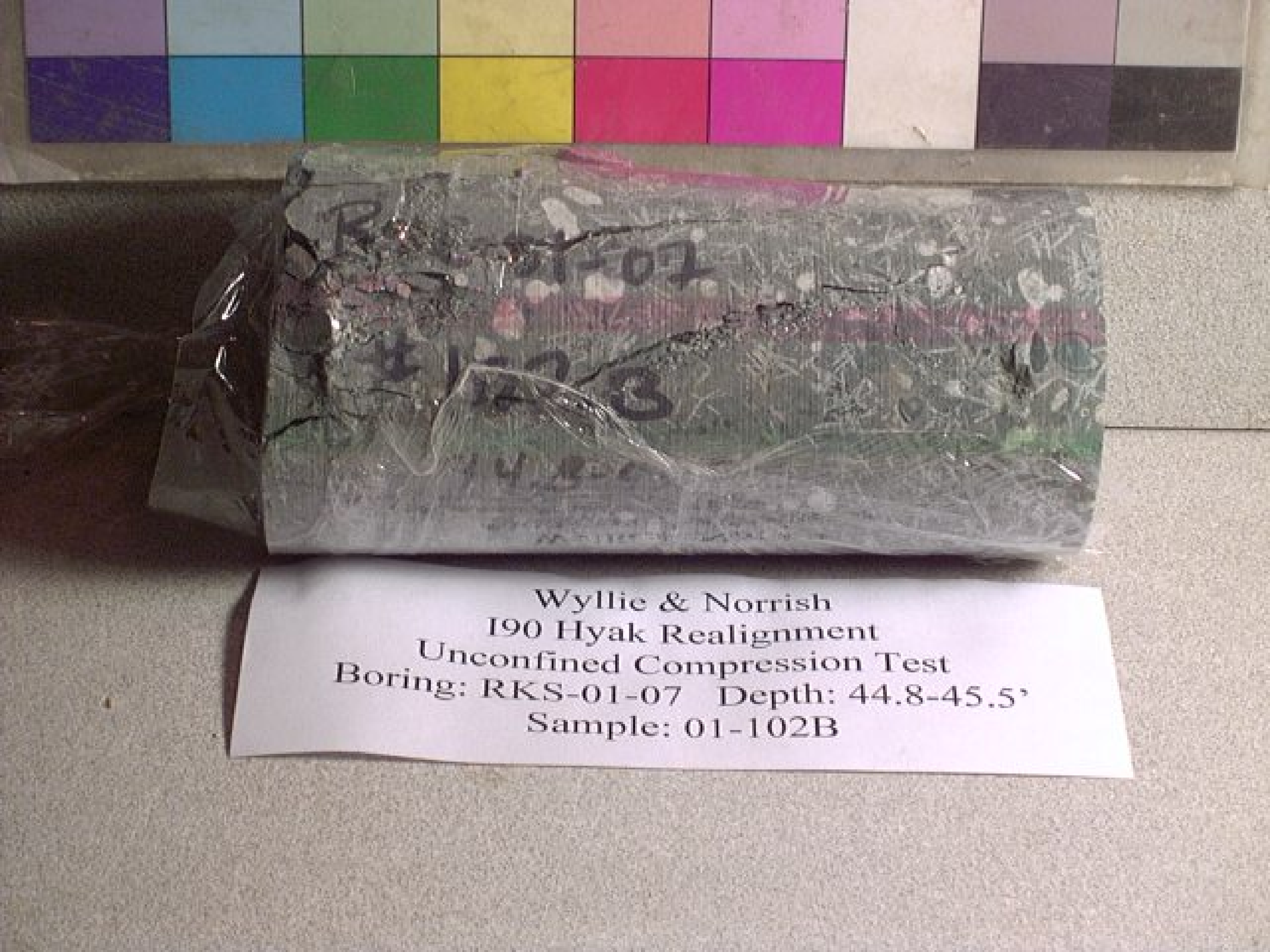
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-04-07   Depth: 25.2-26.0'
Sample: 04-101B


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-04-07 Depth: 25.2-26.0'
Sample: 04-101B


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-03-07   Depth: 71.6-72.3'
Sample: 03-102B


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-03-07   Depth: 71.6-72.3'
Sample: 03-102B


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-01-07 Depth: 44.8-45.5’
Sample: 01-102B


Wyllie & Norrish
I90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-01-07 Depth: 44.8-45.5'
Sample: 01-102B

Geo Test Unlimited (GTU)

Test Equipment Design & Fabrication
Laboratory & Field Testing
Consulting Services

Dr. Anders Bro

January 24, 2008

Rock Testing
East I90 Hyak Extension

Wyllie & Norrish Rock Engineers
17918 NE 27th St.
Redmond, WA 98052

Dear Norm,

This letter report summarizes the unconfined compression, point load, and direct shear tests performed on the samples that you had sent to my lab last month. The report summarizes the test results along with some comments about the testing program that you might find helpful in interpreting the results. The standard test procedures used for these tests are appended to this letter, along with a compact disk containing the data files and photographs of the pre-and post-test samples.

Of the all the samples sent to me, I ended up performing 31 unconfined compression tests, 52 point load tests, and 10 direct shear tests. All of the rock consisted of a meta welded lapilli tuff, with varying degrees of alteration. The hardest rock consisted of a medium blue gray rock. The intermediate strength rock appeared to be a lighter gray, with no blue cast to it. The weakest rock was brown oxide stained rock, clearly weakened by alteration. When cutting the samples with the continuous diamond rimmed rock saw blade, the blue-gray and medium gray rock behaved in a peculiar manner. Even though the rock appeared to cut relatively quickly, it tended to load up the blade and stall the saw. When the length of the cut was short, the saw cut very quickly, however when the length of cut extended (ie half way through the sample), the saw bogged down. I assume it was due to the rock flour that bore against the saw blade increasing the friction and preventing the diamonds from bearing against the virgin rock. The lighter gray rock was significantly easier to cut than the medium blue-gray rock.

Some of the samples contained large clasts of either heavily altered material or they were naturally weak. These light gray materials looked as if they had been a tuff that was either quite weak as deposited, or had partially altered to clay. These inclusions had little cohesion and were either clay-like or silt-like.

The desire was to perform two point load tests (one axial and one diametral test) on the companion samples to the unconfined compression tests. For a few of the samples, no companion samples were available and I tested what I could of the sample cut-off pieces. Four of the direct shear tests were performed on saw-cut interfaces. These samples were extracted from the hard parent rock and were ground flat with a diamond surfacing plate. The remaining six direct shear sample consisted of fairly planar filled joints, typically dipping at high angles. (See the raw data sheets for the measured dip angles.)

Unconfined Compression and Point Load Testing

The objective of this testing program was to perform a set of unconfined compression tests along with companion axial and diametral point load tests so that a reasonable correlation between the test values could be developed. For each pair of samples (labeled –A and –B) the least fractured samples were chosen for the unconfined compression tests. An effort was also made to cut unfractured samples for the axial point load tests. It was felt that it should be possible to find a suitable diametral point load sample from the remaining core.

The tests were performed according to the appended test procedures and the test results are tabulated as follows:

Unconfined Compressive Strength and Point Load Test Results

Boring/ Sample #	Depth (ft.)	Description	Density (pcf)	Corrected Point Load (psi)	UC Strength (psi)
SI-1-07 #101	32.0-32.7	Medium brown meta welded lapilli tuff, altered and friable with an open oxide coated fracture.	155.1		4680
SI-2-07 #103A	53.4-54.0	Medium brown meta welded lapilli tuff, altered with several oxide healed joints.	160.5	203[1.2.d.]	2901
SI-4-07 #101A	23.6-24.5	Medium blue gray meta welded lapilli tuff with a glued fracture at one end.	162.9		23,469
SI-4-07 #101B	24.5-25.3	Medium blue gray meta welded lapilli tuff.		1531[d] 993[a]	
SI-5-07 #102A	33.9-34.8	Light greenish gray meta welded lapilli tuff with no apparent planes of weakness.	165.0		29,523
SI-5-07 #102B	34.8-35.7	Light greenish gray meta welded lapilli tuff.		1170[d] 1043[a]	
SI-5-07 #103	56.9-57.6	Medium brown meta welded lapilli tuff, slightly altered with two minor oxide stained non-through-going joints.	158.6	95[2.d.]	3782
SI-7-07 #101A	35.6-36.3	Medium blue gray meta welded lapilli tuff.		993[1.d.] 774[a]	
SI-7-07 #101B	36.9-37.4	Medium gray meta welded lapilli tuff with slight oxide staining but no apparent planes of weakness.	163.5		26,444
SI-9-07 #201	42.4-43.1	Light to medium brown meta welded lapilli tuff, somewhat friable with several oxide stained joints.	158.9	72[2.d.]	3348
SI-10-07 #101A	24.7-25.4	Medium blue gray meta welded lapilli tuff with no apparent planes of weakness.	163.5		21,770
SI-10-07 #101B	26.8-27.6	Medium blue gray meta welded lapilli tuff.		1464[d] 934[a]	

Unconfined Compressive Strength and Point Load Test Results (cont.)

RKS-12-07 #101A	28.9-29.5	Medium gray meta welded lapilli tuff.		1365[d] 1235[a]	
RKS-12-07 #101B	29.5-30.3	Medium blue gray meta welded lapilli tuff with a few light green zones of matrix, with no apparent planes of weakness.	164.0		31,257
RKS-12-07 #103A	124.0-124.6	Medium gray meta welded lapilli tuff.		848[d] 288[2.a.]	
RKS-12-07 #103B	124.6-125.3	Medium blue gray meta welded lapilli tuff with an axial healed hairline joint.	164.3		23,952
RKS-13-07 #102	19.0-19.7	Medium brown meta welded lapilli tuff, somewhat altered with zones of lighter brown, more severely altered matrix.	155.7	91[2.d.]	4120
RKS-13-07 #104A	44.1-44.6	Light greenish gray meta welded lapilli tuff, slightly altered with light green, more altered inclusions with no apparent planes of weakness.	162.6		8184
RKS-13-07 #104B	44.6-45.1	Light greenish gray meta welded lapilli tuff.		425[d] 801[a]	
RKS-14-07 #103A	78.2-78.8	Light greenish gray meta welded lapilli tuff.		259[d] 222[a]	
RKS-14-07 #103B	78.8-79.4	Light greenish gray meta welded lapilli tuff, slightly altered with light green, more altered inclusions with one minor end fracture.	159.0		5805
RKS-15-07 #102A	20.5-21.1	Brown fractured and altered meta welded lapilli tuff.		121[d] 37[a]	
RKS-15-07 #102B	21.1-21.8	Medium brown meta welded lapilli tuff, altered with weak end fractures that have been glued.	151.6		3250
RKS-15-07 #105A	120.0-120.5	Medium brown meta welded lapilli tuff, altered with a few thin planar zones of weakness.	159.6		8287
RKS-15-07 #105B	120.5-121.1	Light brownish gray fractured and altered meta welded lapilli tuff.		366[d] 148[a]	
RKS-16-07 #101A	47.0-47.6	Light brownish gray fractured and altered meta welded lapilli tuff.		397[d] 277[a]	
RKS-16-07 #101B	47.6-48.2	Medium brown meta welded lapilli tuff, oxide stained with a small light gray clay(?) zone and one non-through-going fracture.	159.3		6408

Unconfined Compressive Strength and Point Load Test Results (cont.)

RKS-17-07 #102	53.3-54.0	Meta welded lapilli tuff, medium brown and blue gray clasts in a light gray matrix, with a few non-through-going fractures.	156.2	430[d]	7767
RKS-18-07 #102A	72.0-72.5	Dark gray fractured meta welded lapilli tuff.		317[d] 193[a]	
RKS-18-07 #102B	72.5-72.9	Dark gray heavily fractured meta welded lapilli tuff.	159.4		6005
RKS-19-07 #102	30.4-31.4	Light gray meta welded lapilli tuff with several light blue inclusions altered to clay(?) with a glued end fracture.	156.4	259[d]	5959
RKS-19-07 #103A	55.6-56.3	Light gray meta welded lapilli tuff with light green clasts.		342[d] 405[a]	
RKS-19-07 #103B	56.3-57.0	Light gray meta welded lapilli tuff, with light blue inclusions altered to clay(?).	160.9		9148
RKS-20-07 #102A	64.8-65.4	Light gray meta welded lapilli tuff, with light blue inclusions altered to clay(?).	160.4		8358
RKS-20-07 #102B	65.4-66.1	Light gray meta welded lapilli tuff with light green clasts.		282[d] 230[a]	
RKS-22-07 #101A	11.7-12.5	Medium gray meta welded lapilli tuff with a tight end fracture.	166.0		9327
RKS-22-07 #101B	12.5-13.4	Light gray meta welded lapilli tuff with light green clasts (less altered).		645[d] 495[a]	
RKS-23-07 #101A	10.3-11.0	Medium blue gray meta welded lapilli tuff with no apparent planes of weakness.	163.2		23,917
RKS-23-07 #101B	11.0-11.7	Medium blue gray meta welded lapilli tuff.		996[d] 1097[a]	
RKS-26-07 #101A	28.2-28.8	Medium greenish gray meta welded lapilli tuff.		974[d] 852[1.a.]	
RKS-26-07 #101B	32.1-32.8	Medium blue gray meta welded lapilli tuff with no apparent planes of weakness.	163.9		16,267
RKS-27-07 #102A	28.5-29.2	Light to medium gray meta welded lapilli tuff with a few altered clasts.	164.6		18,597
RKS-27-07 #102B	29.2-29.9	Medium greenish gray meta welded lapilli tuff.		1197[d] 1061[a]	

Unconfined Compressive Strength and Point Load Test Results (cont.)

RKS-28-07 #102A	65.4-66.0	Light gray meta welded lapilli tuff with no apparent planes of weakness.	164.0		10,535
RKS-28-07 #102B	66.0-66.6	Light gray meta welded lapilli tuff.		468[d] 1286[a]	
RKS-28-07 #201	33.0-33.8	Medium brown meta welded lapilli tuff with a tight axial non-through-going fracture..	158.3	128[1.2.d.]	3588
RKS-28-07 #202	27.8-28.5	Medium brown meta welded lapilli tuff with two major axial fractures.	156.2	85[d]	1970
RKS-29-07 #102A	18.8-19.5	Medium gray meta welded lapilli tuff with no apparent planes of weakness. (finer clasts than the other samples)	159.4		14,605
RKS-29-07 #102B	20.6-21.2	Medium gray meta welded lapilli tuff.		602[d] 384[a]	
RKS-30-07 #103A	55.1-55.8	Medium blue gray meta welded lapilli tuff with no apparent planes of weakness.	161.7		43,320
RKS-30-07 #103B	55.8-56.4	Medium blue gray meta welded lapilli tuff.		1280[d] 1134[a]	
RKS-31-07 #103A	84.8-85.6	Medium blue gray meta welded lapilli tuff.		1580[d] 1403[a]	
RKS-31-07 #103B	83.5-84.3	Medium gray meta welded lapilli tuff with no apparent planes of weakness.	162.4		38,505

Notes: a. Axial Point Loading
d. Diametral Point Loading
1. Invalid – failure did not pass through both points of loading.
2. Failed along existing planes of weakness.

The most unique sample of this group were the samples from Boring RKS-18-07 from 72.0-72.9’. This rock looked a little more like basalt and was highly fractured with little if any cohesion. It was interesting to note that despite the high degree of fracturing, it still had a respectable strength (6005 psi). This sample failed in a somewhat ductile manner that I attribute to the interlocking of the short-length, non-through-going fractures.

Most of the rock appeared to characterized by a low grade of metamorphism in which the rock had been subjected to high temperature, but not necessarily elevated pressure. The rock had clearly been altered to varying degrees and some of the clasts were quite porous, a characteristic that I attribute to the clasts, as-placed. Some of these clasts had likely altered a bit to clay, but their texture was not particularly plastic, indicating a limited alteration.

The medium blue gray colored rock was clearly the strongest material, with strengths ranging from 21,770 psi to an extremely high strength of 43,320 psi. It may be that this rock is characterized by a higher grade of metamorphism and it clearly was not appreciably altered.

The brown altered rock was the weakest with strengths generally below 5000 psi. The weak brown colored rock was typically altered and jointed and the weakness seemed to be associated with failure along existing planes of weakness. These materials were also quite weak in the point load tests in which failures more often than not developed along pre-existing fractures.

The intermediate strength rocks generally consisted of the lighter creamy gray materials and seemed to fall in the 5000-10,000 psi range. Failures of these samples typically developed through the intact material.

Direct Shear Testing

Four tests were performed on saw-cut and ground interfaces created from strong sections of the intact rock. The other six samples consisted of clay filled discontinuities. Six additional direct shear samples were supplied for possible testing, but these were deemed of poorer quality or duplicated the samples that were selected for testing. The target normal stresses for these multistage tests were 10, 20, and 40 psi. They were tested according to the appended test procedures.

The saw-cut interfaces were created by cutting the intact core normal to the core axis and then grinding the resulting flat surfaces with a 120 grit diamond disk such as is used for creating thin sections. The purpose of the diamond grinding was to eliminate any ridges that might have developed during the sample cutting operation and to create a flat planar surface.

Before cutting the filled joint samples, the core was wrapped with heat-shrink plastic wrap. The purpose of this wrap was to reduce wash-out of the weak and erodible joint filling while cutting the samples to length. The heat-shrink wrap also helped hold the two sample halves together, reducing sample disturbance. The results were quite satisfactory, particularly in light of earlier experiences with trying to cut similar filled joints when not so confined.

The following table summarizes the direct shear test results:

Direct Shear Test Results

Boring/ Sample #	Depth (ft.)	Description	Shear Intercept (psi)	Friction Angle (deg.)
SI-2-07 #102A	40.4-41.4	Planar clay filled joint in medium gray and brown gray meta welded lapilli tuff. Light yellowish brown filling about 1/8” thick.	1.1^{i} 1.7^{f}	15.7^{i} 11.1^{f}
SI-2-07 #105	84.6-86.0	Planar clay filled joint in blue gray meta welded lapilli tuff. White filling with light brown interlacings about 1/8-3/8” thick.	6.6^{i} 1.2^{f}	16.7^{i} 13.0^{f}
SI-10-07 #104	43.4-44.0	Planar clay filled joint in fractured blue gray meta welded lapilli tuff. Light bluish white filling 1/4-5/8” thick with rock fragments.	3.2^{i} 1.9^{f}	16.9^{i} 15.7^{f}
RKS-13-07 #103	39.0-39.5	Wavy filled joint in medium brownish gray meta welded lapilli tuff. Light yellowish brown filling <1/8” thick.	4.6^{i} 1.7^{f}	18.07^{i} 18.5^{f}
RKS-19-07 #101	33.0-33.7	Planar filled joint in light gray meta welded lapilli tuff. Thick light bluish white filling.	0.6^{i} 3.3^{f}	19.9^{i} 15.9^{f}

Direct Shear Test Results (cont.)

RKS-19-07 #103B	56.3-57.0	Saw-cut and ground interface in light gray meta welded lapilli tuff with a few light bluish white friable clasts.	0.2^{i} 1.7^{f}	27.6^{i} 31.5^{f}
RKS-22-07 #101A	11.7-12.5	Saw-cut and ground interface in light gray meta welded lapilli tuff.	$na(-0.6)^{i}$ 0.8^{f}	28.1^{i} 33.3^{f}
RKS-24-07 #102	36.3-36.9	Filled shear zone in blue gray meta welded lapilli tuff. Light bluish white filling in 5/8-1" wide shear zone with rock flakes.	3.7^{i} na[1]	14.5^{i} na[1]
RKS-29-07 #102A	18.8-19.5	Saw-cut and ground interface in medium greenish gray meta welded lapilli tuff, fine grained with clasts <1/8".	$na(-0.4)^{i}$ 0.6^{f}	26.7^{i} 31.1^{f}
RKS-30-07 #103A	55.1-55.6	Saw-cut and ground interface in medium blue gray meta welded lapilli tuff.	0.1^{i} 0.8^{f}	33.4^{i} 39.2^{f}

Notes: i. Initial strength parameter
f. Final strength parameter
na. The shear intercept is negative and not applicable
1. The shear box rotated and developed box-to-box contact preventing the evaluation of final values.

The saw-cut sample tests resulted in low shear intercepts of between –0.6 and 1.7. The negative intercepts are clearly inapplicable and are likely due to the strengthening of the interface as it incurred a shear displacement, thus effectively rotating the initial shear envelope in a counterclockwise manner, driving the intercept in a more negative direction. I have often encountered such negative intercepts for saw-cut interfaces and think that it is appropriate to simply ignore them and assume a zero intercept.

The saw-cut sample initial friction angles ranged from 26.7 to 33.4^{o}, with the three more altered materials resulting in a spread of 26.7-28.1^{o} . The least altered material, the blue gray rock, resulted in the highest friction angle, 33.4^{o} . An interesting aspect of these saw-cut tests was that all of the samples exhibited displacement hardening, and the final friction angles were on the order of 4-5^{o} greater than the initial values. On post-test inspection, the interfaces were found to have been polished as a result of the testing. Patches of the interface were polished to the extent that they would readily reflect light. I tried to photograph this reflectivity, but could not capture the reflections in a convincing manner. It appears that this more polished surface is slightly more frictional than the slightly rougher ground interface. I am not sure which strength parameter would be more appropriate for characterizing the basic friction angle.

It should be noted that, as with all saw-cut and ground samples that I have tested, the interfaces exhibited a marked stick-slip behavior. The slip-action was accompanied by an audible "chunk" sound and was decidedly a dynamic event. As such, the stick-slip minima are a consequence of the dynamic overshoot of the slip event. The static friction angles are represented by the stick-slip peaks (used in this report to evaluate the failure envelopes) and the mid-points of the slip events likely represent the dynamic friction angles for this interface.

The filled joint tests were quite interesting. With the exception of Sample #102 from Boring RKS-24-07, in which the box rotated too much to obtain a set of final strength values, the remaining tests were of high quality, and at the normal stresses used, did not squeeze any appreciable amount of filling from the filled joints. For these samples, the initial shear intercepts were generally on the order of 3 psi whereas the final intercepts were a bit lower, typically on the order of 1 psi or so. The initial friction angles were quite low, in the mid-teens, whereas the final values were about 3-5 degrees lower. These low values are characteristic of clay fillings.

One of the most interesting aspects of these clay filled joint tests was the location of the shear plane. Often testing of such filled interfaces is precluded due to squeezing of the filling out of the joint. In instances where the filling is quite thick, another approach is taken of simply testing the filling material in a soil direct shear apparatus. Based on the behavior of these samples, I am starting to doubt the applicability of such a testing approach. That which was unique about these tests was that the fillings were strong enough to withstand the normal stresses without squeezing out of the joints. Thus good quality tests could be performed on these samples. A telling observation was that the samples generally sheared along the clay-rock interface. Clearly this interface was the weakest link in the samples. It would be very useful to know how strong the filling is in comparison to this rock-clay interface. Only then could one know how unconservative one might be in testing just the clay fillings.

Sample #101 from Boring RKS-19-07 was somewhat problematic in the data reduction. It appeared that some of the altered parent rock penetrated through the filling and developed a rock-to-rock contact, significantly strengthening the interface. This strengthening can be seen at shear displacements of between 0.15 and 0.2 inches. I have done my best to choose the initial strengths (Expanding the displacement axis helps greatly.), but as with all of these test results, the engineer should evaluate the chosen strengths and assess the suitability of these choices for the design goals. It should also be noted that quite large shear displacements were required to reach final strength values. By the end of the test there was not a sufficient stroke remaining to measure the third final stage. Thus the final strength parameters for this sample are based on only two stages.

If you have any questions regarding these test results or the test procedures, please feel free to contact me so that we can discuss any of your concerns.

for GeoTest Unlimited

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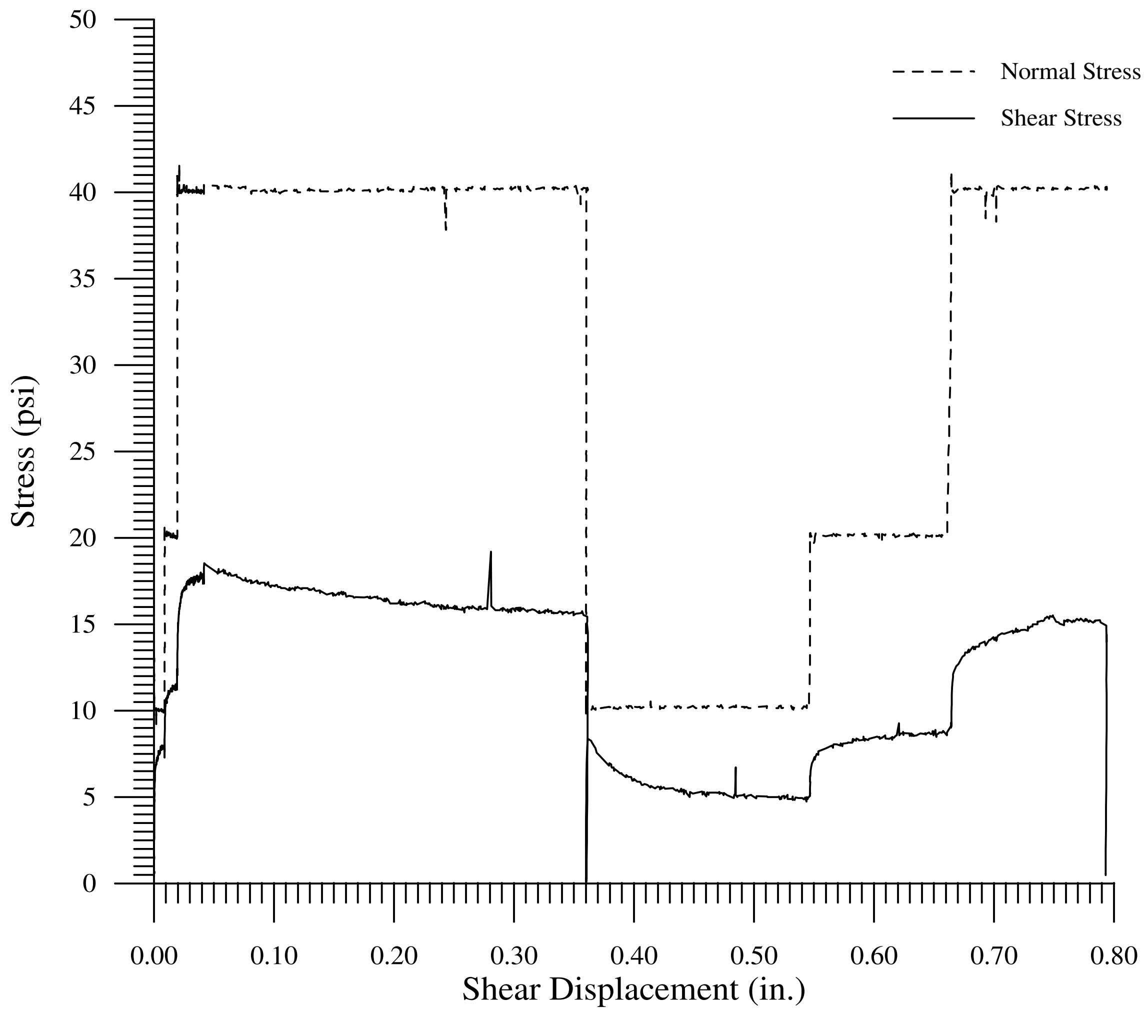
Dr. Anders Bro



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 103
Boring: RKS-13-07
Depth: 39.0-39.5'

DESCRIPTION

Wavy filled joint in medium brownish gray meta welded lapilli tuff. Light yellowish brown filling <1/8" thick.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.0	7.8
	20.1	11.3
	40.0	17.6
Final	10.0	4.9
	20.0	8.7
	40.2	15.1

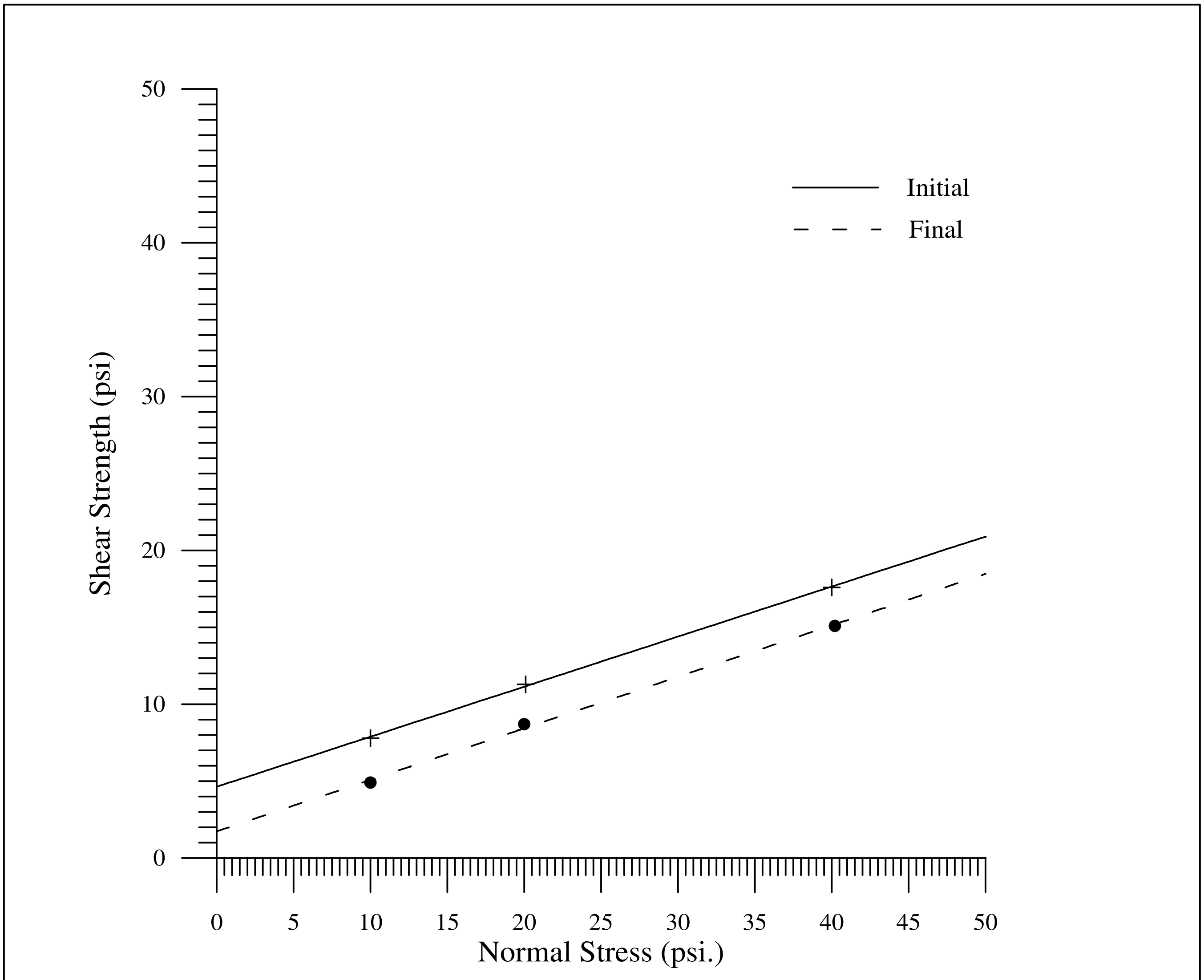
Geo Test Unlimited (GTU)
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: 03-2007

Test Date: January 22, 2008



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 103
Boring: RKS-13-07
Depth: 39.0-39.5'

DESCRIPTION

Wavy filled joint in medium brownish gray meta welded lapilli tuff. Light yellowish brown filling <1/8" thick.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	4.6	18.0
Final	1.7	18.5

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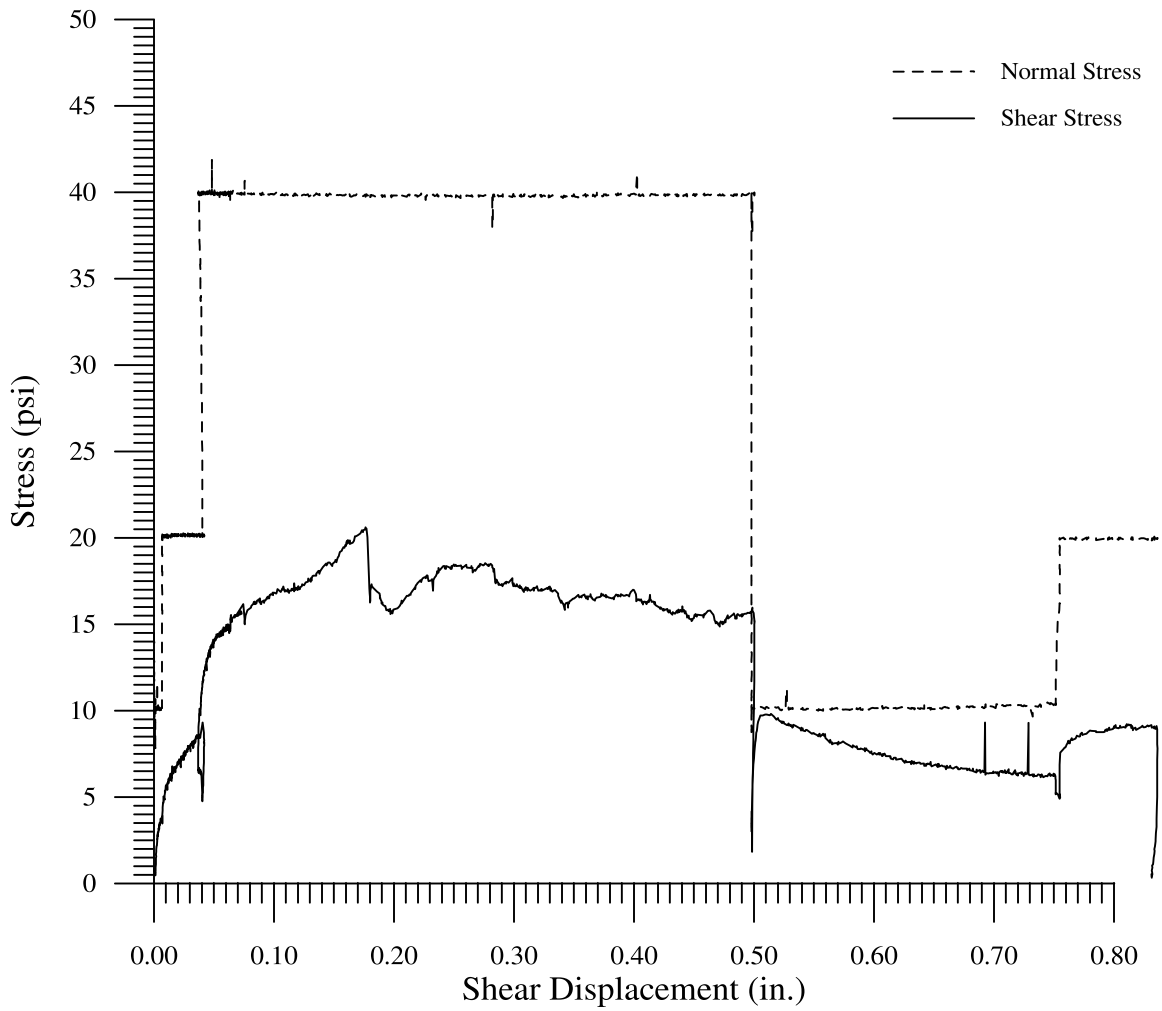

DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 101
Boring: RKS-19-07
Depth: 33.0-33.7'

DESCRIPTION

Planar filled joint in light gray meta welded lapilli tuff. Thick light bluish white filling.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.0	3.8
	20.1	8.5
	39.9	14.8
Final	10.2	6.2
	20.0	9.0

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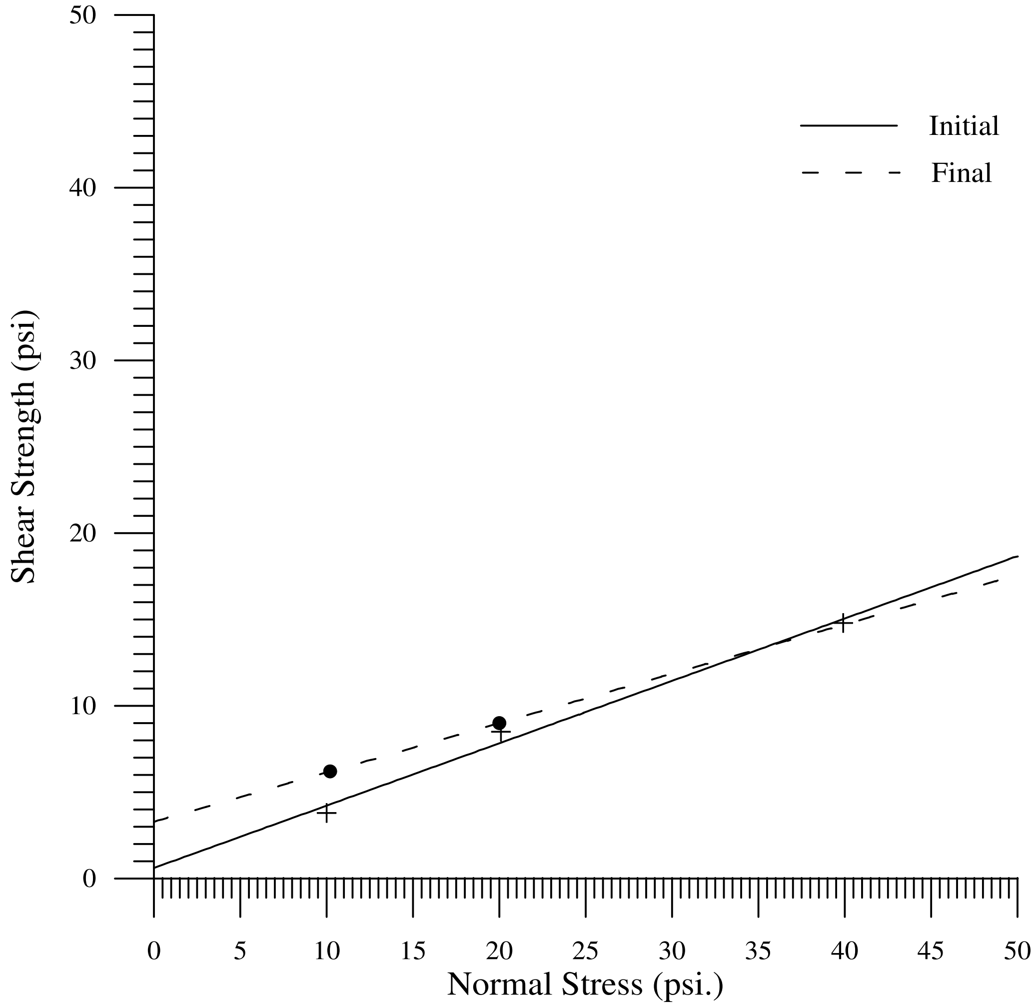
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 23, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 101
Boring: RKS-19-07
Depth: 33.0-33.7'

DESCRIPTION

Planar filled joint in light gray meta welded lapilli tuff. Thick light bluish white filling.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	0.6	19.9
Final	3.3	15.9

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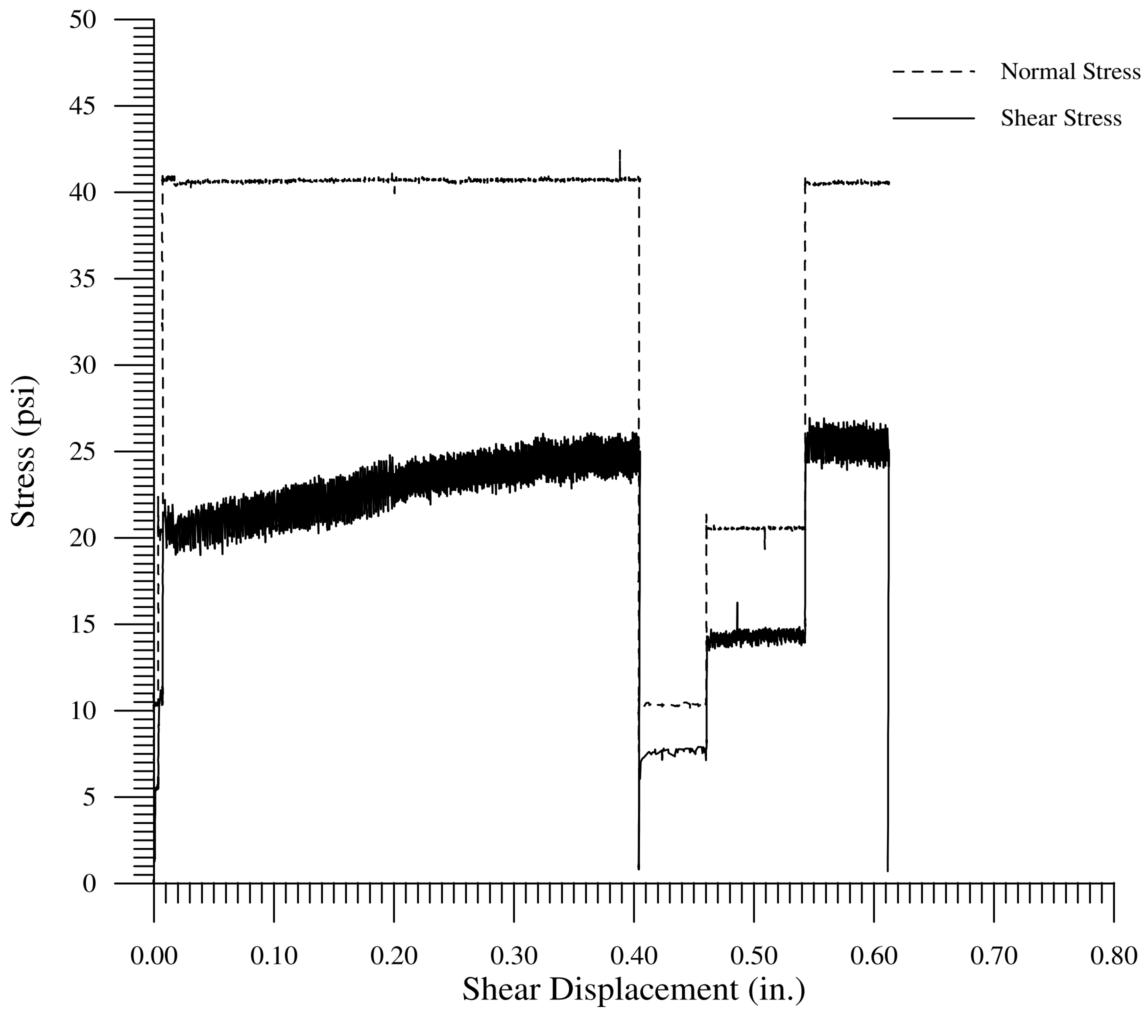
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 23, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 103B
Boring: RKS-19-07
Depth: 56.3-57.0'

DESCRIPTION

Saw-cut interface in light gray meta welded lapilli tuff with a few large light bluish white friable clasts.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.3	5.6
	20.5	10.9
	40.7	21.5
Final	10.3	7.7
	20.5	14.6
	40.5	26.3

Geo Test Unlimited (G T U)
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Client: Wyllie & Norrish Engineers
17918 NE 27th St.
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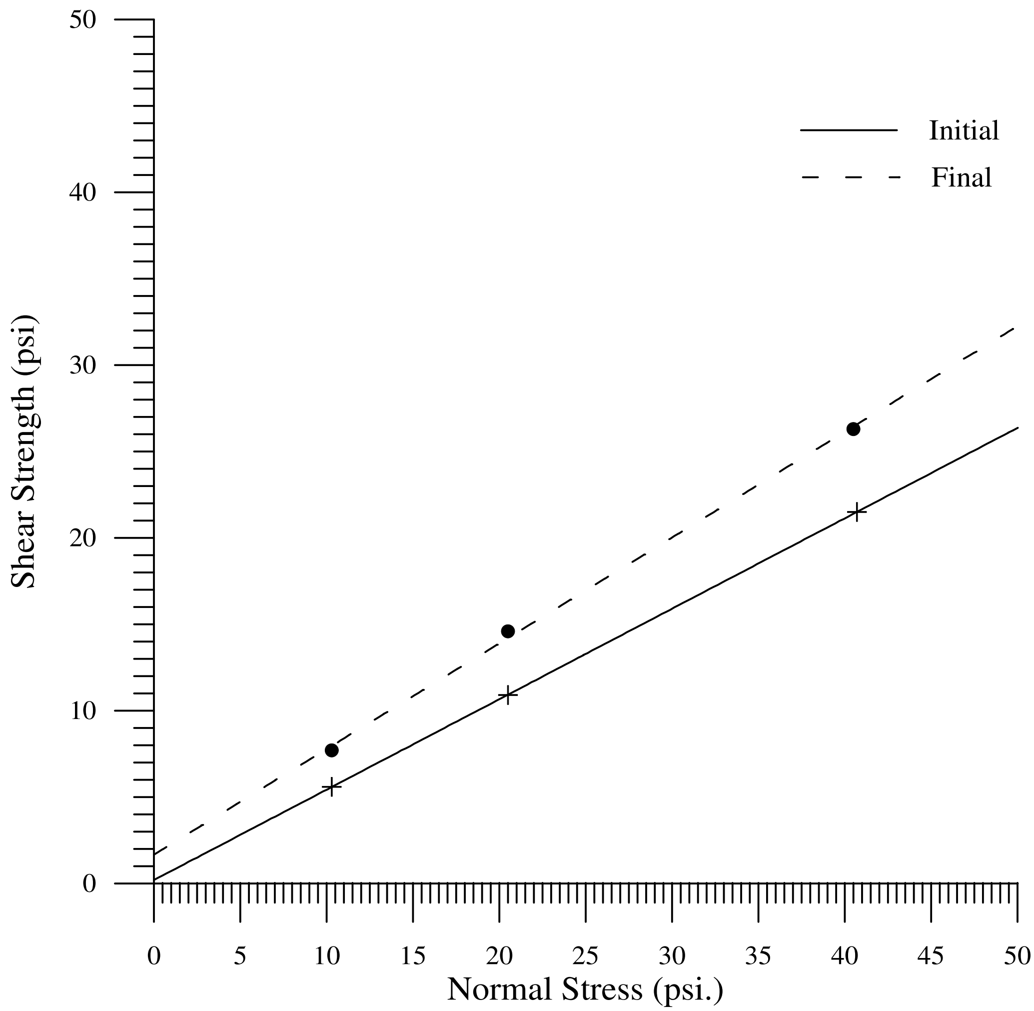
Project: East I-90 Hyak Realignment

Project Number: 03-2007

Test Date: January 21, 2008



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 103B
Boring: RKS-19-07
Depth: 56.3-57.0'

DESCRIPTION

Saw-cut interface in light gray meta welded lapilli tuff with a few large light bluish white friable clasts.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	0.2	27.6
Final	1.7	31.5

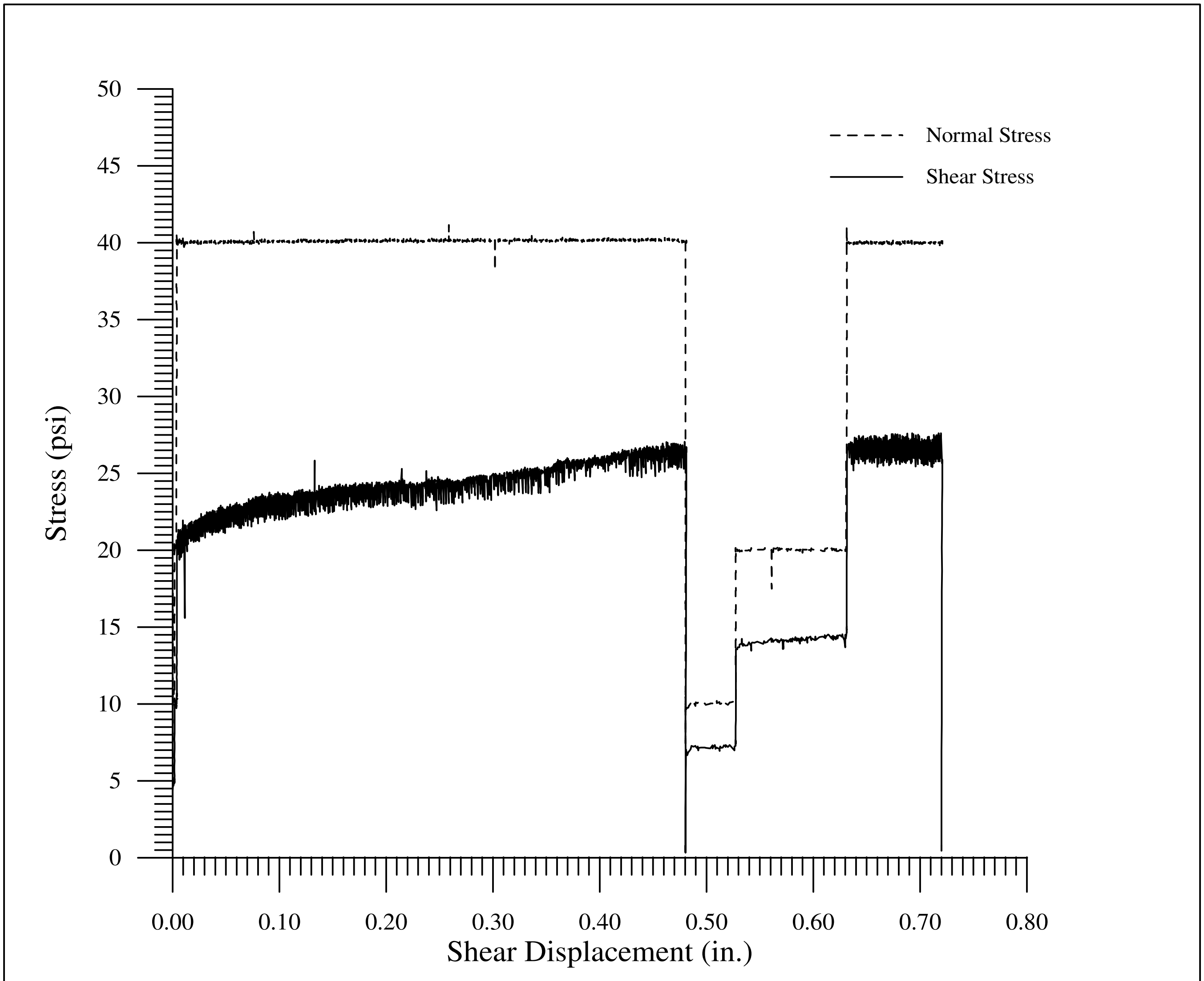
Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 21, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 101A
Boring: RKS-22-07
Depth: 11.7-12.5'

DESCRIPTION

Saw-cut interface in light gray
meta welded lapilli tuff.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.1	5.0
	20.2	10.0
	40.0	20.9
Final	9.9	7.1
	19.9	14.3
	40.0	27.0

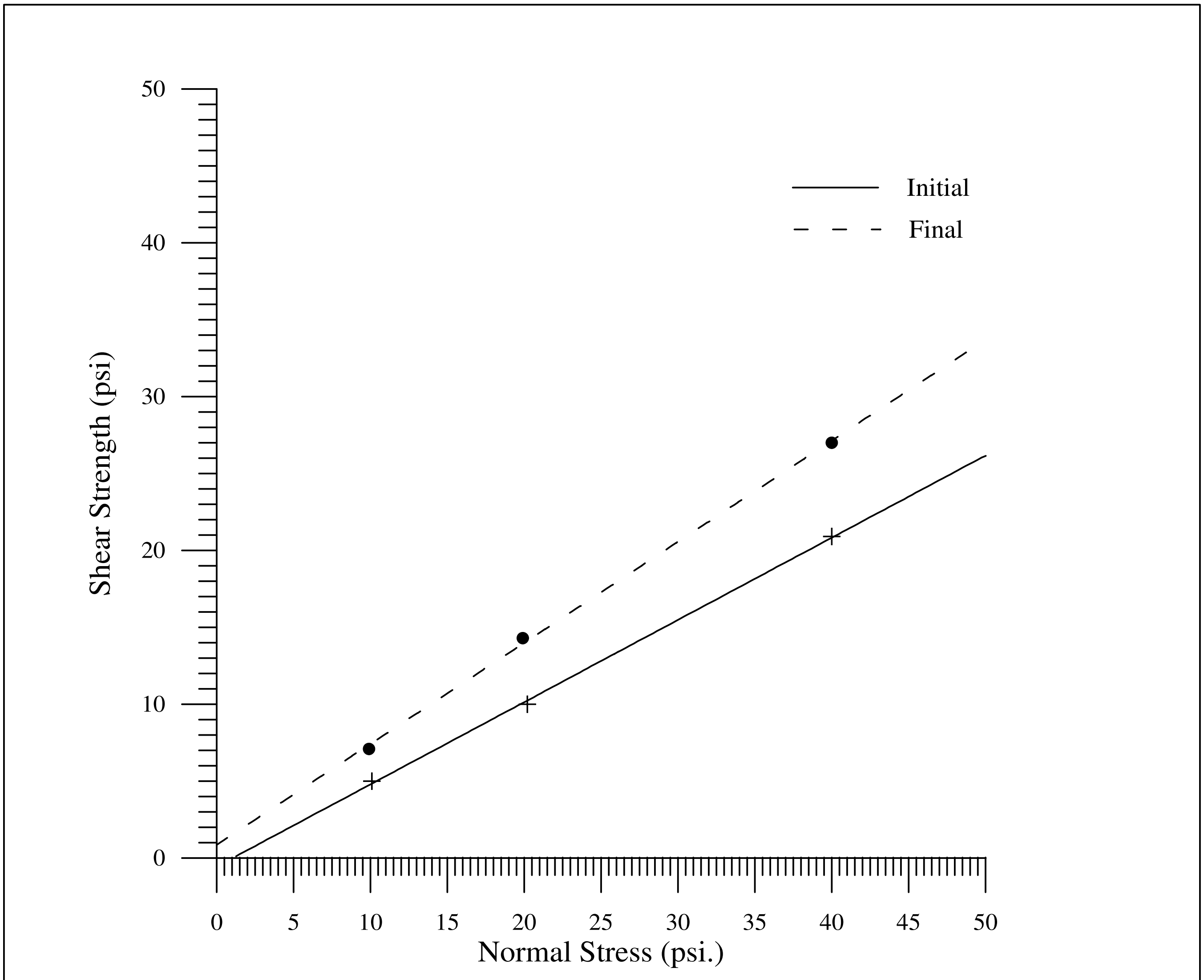
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 21, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 101A
Boring: RKS-22-07
Depth: 11.7-12.5'

DESCRIPTION

Saw-cut interface in light gray meta welded lapilli tuff.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	na(-0.6)	28.1
Final	0.8	33.3

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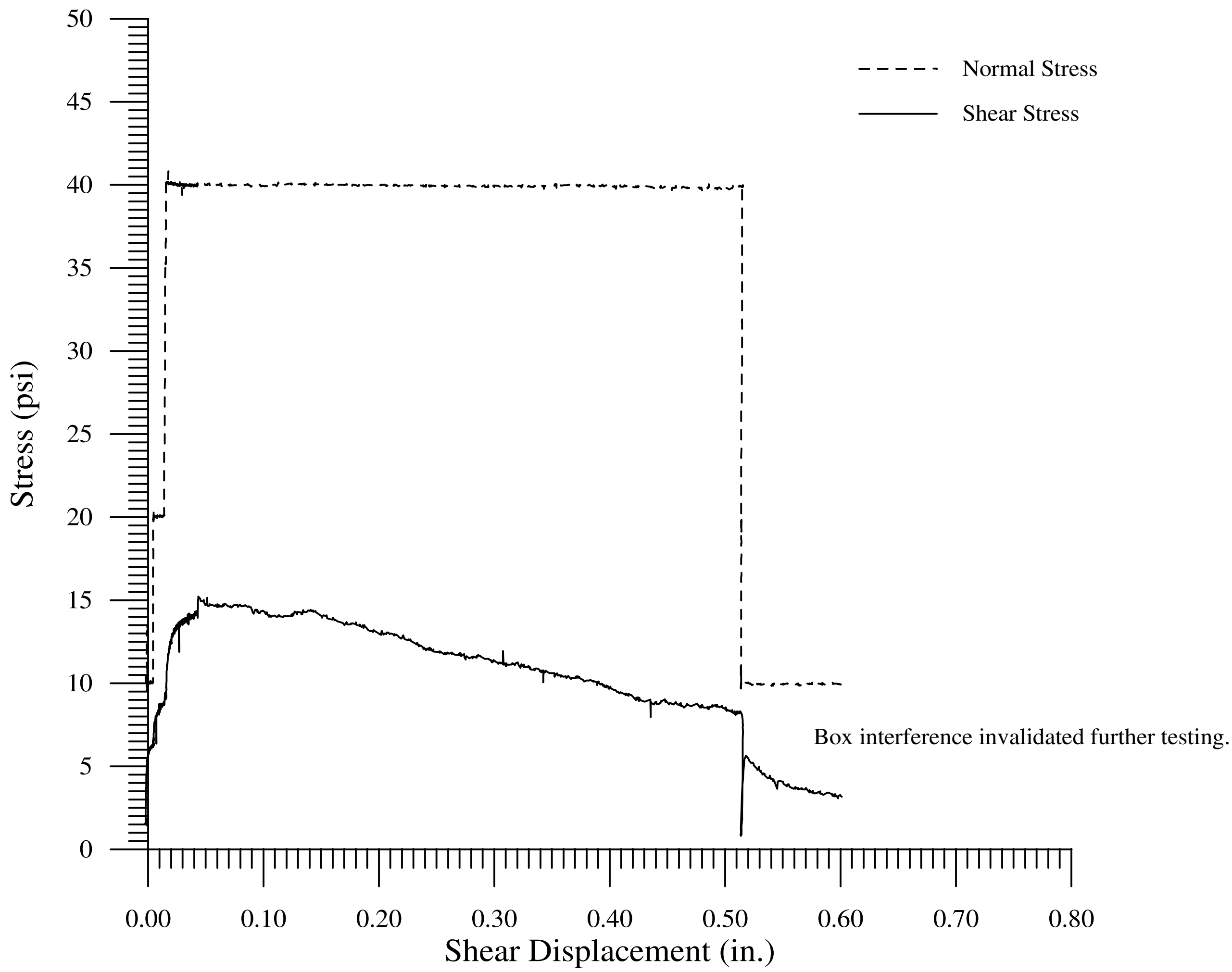
Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 21, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 102
Boring: RKS-24-07
Depth: 36.3-36.9'

DESCRIPTION

Filled shear zone in blue gray meta welded lapilli tuff. Light bluish white filling in 5/8-1" wide shear zone with rock flakes.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.0	6.2
	20.0	8.9
	40.0	14.0
Final	na	na

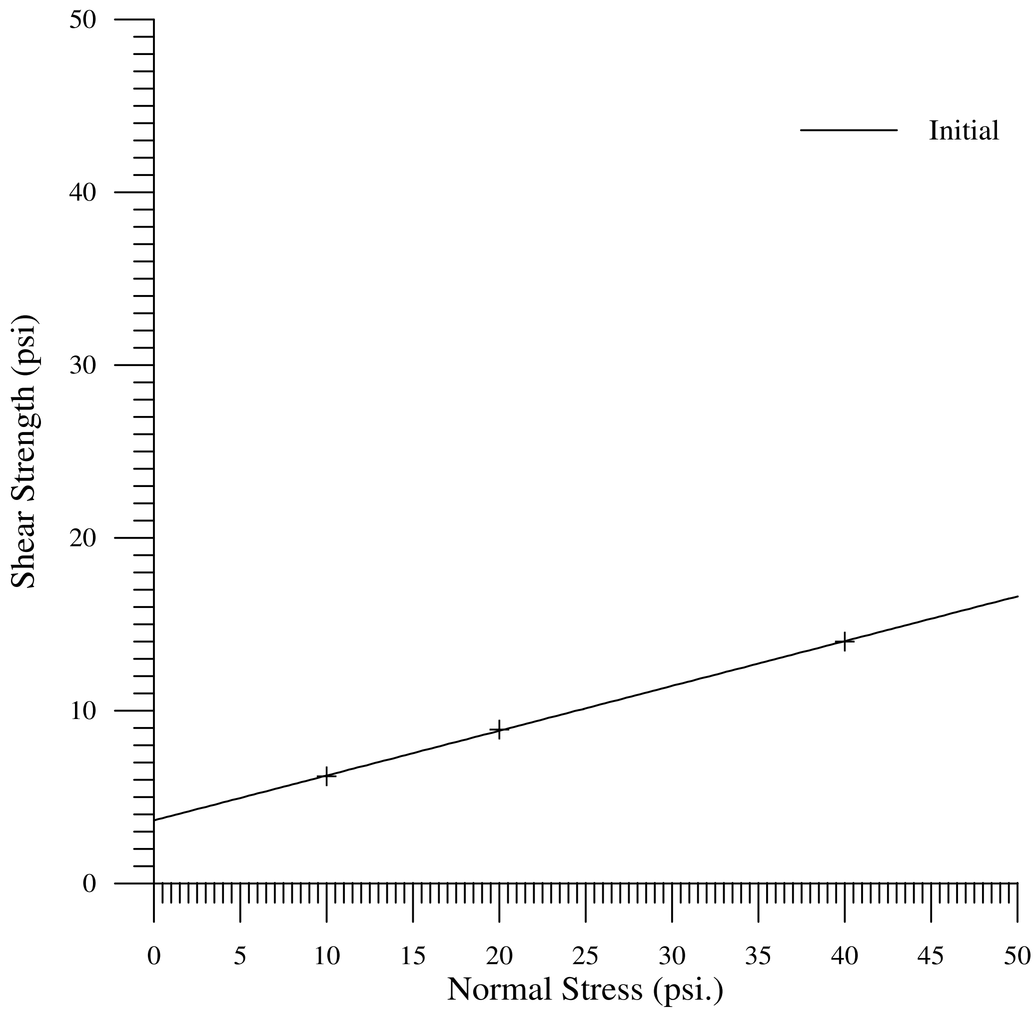
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 23, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 102
Boring: RKS-24-07
Depth: 36.3-36.9'

DESCRIPTION

Filled shear zone in blue gray meta welded lapilli tuff. Light bluish white filling in 5/8-1" wide shear zone with rock flakes.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	3.7	14.5
Final	na	na

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Client: **Wyllie & Norrish Engineers**
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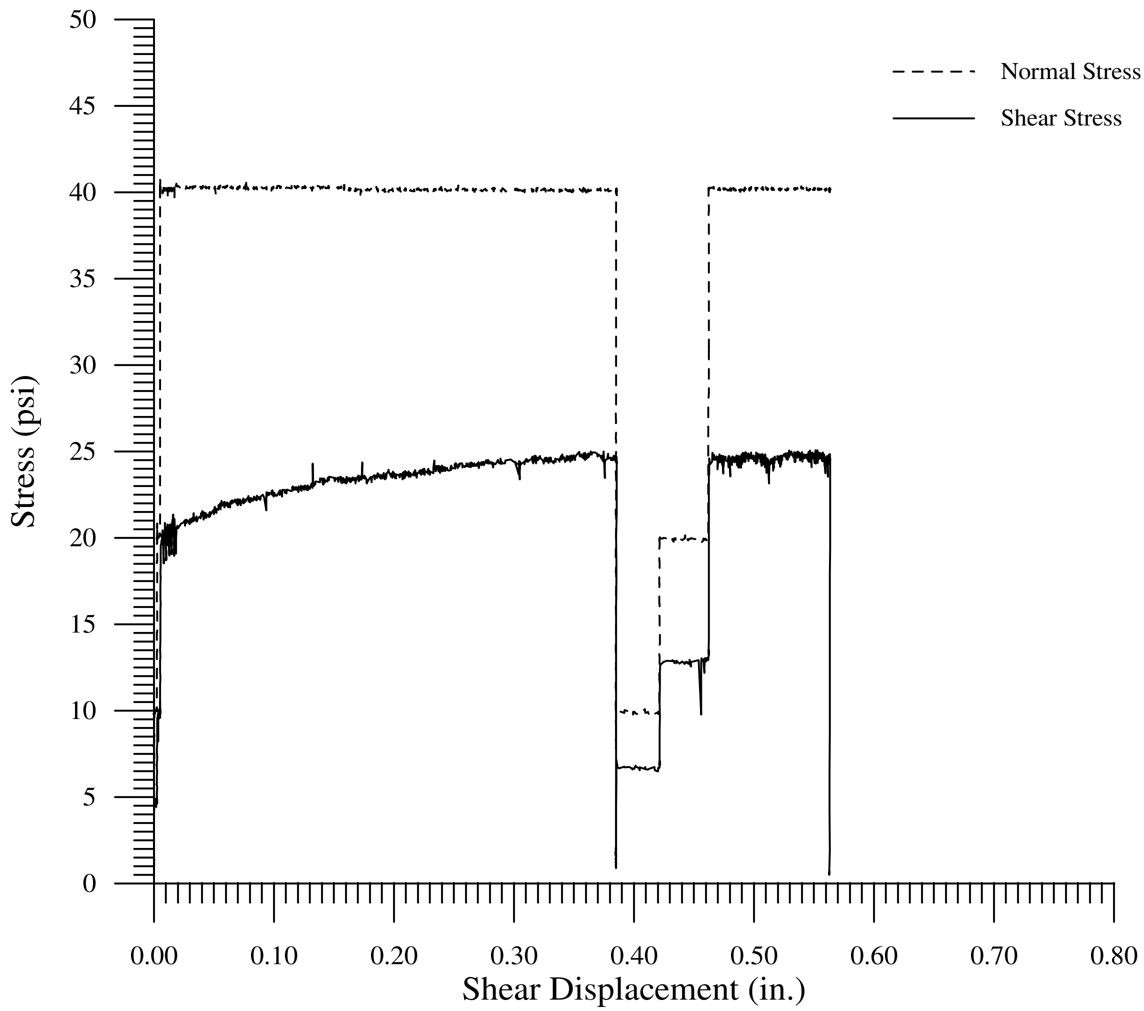
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 23, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 102A
Boring: RKS-29-07
Depth: 18.8-19.5'

DESCRIPTION

Saw-cut interface in medium greenish gray meta welded lapilli tuff, fine grained with clasts <1/8".

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.0	4.7
	20.2	9.8
	40.0	19.8
Final	9.9	6.5
	19.9	12.8
	40.2	24.8

Geo Test Unlimited
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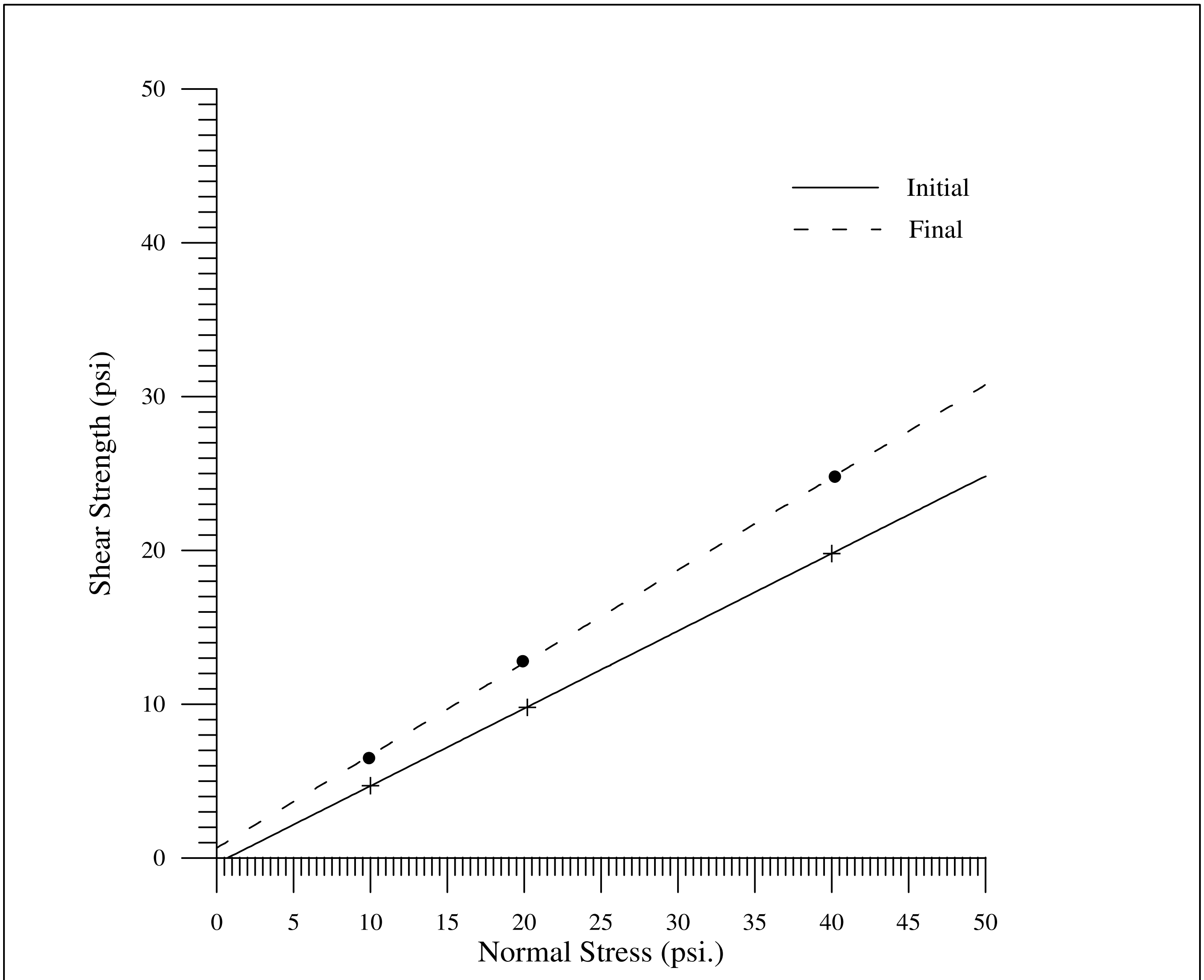
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 21, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 102A
Boring: RKS-29-07
Depth: 18.8-19.5'

DESCRIPTION

Saw-cut interface in medium greenish gray meta welded lapilli tuff, fine grained with clasts< 1/8".

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	na(-0.4)	26.7
Final	0.6	31.1

Geo Test Unlimited GTU

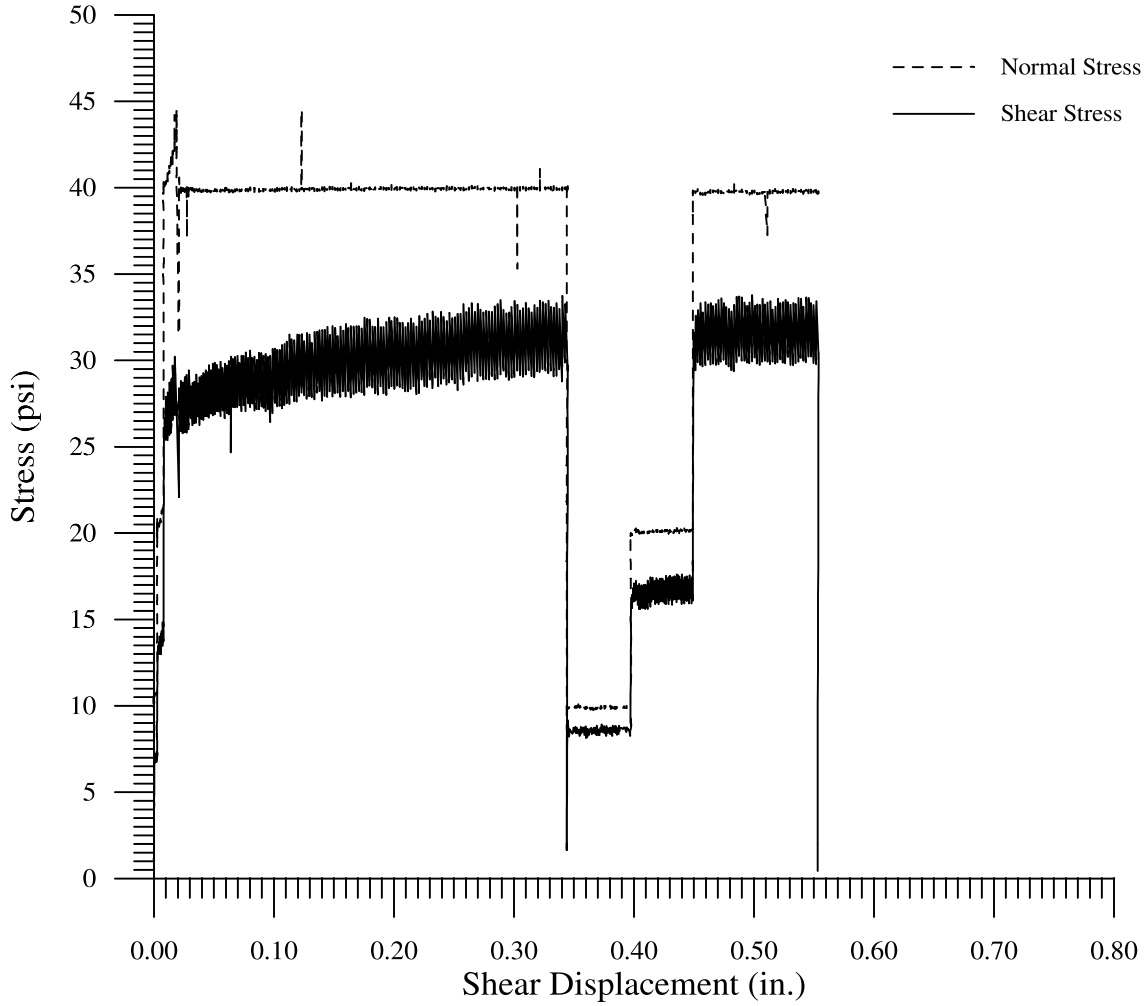
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 21, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 103A
Boring: RKS-30-07
Depth: 55.1-55.6'

DESCRIPTION

Saw-cut interface in medium blue gray meta welded lapilli tuff.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.6	7.0
	20.5	13.7
	40.1	26.5
Final	10.0	8.8
	20.2	17.5
	39.8	33.2

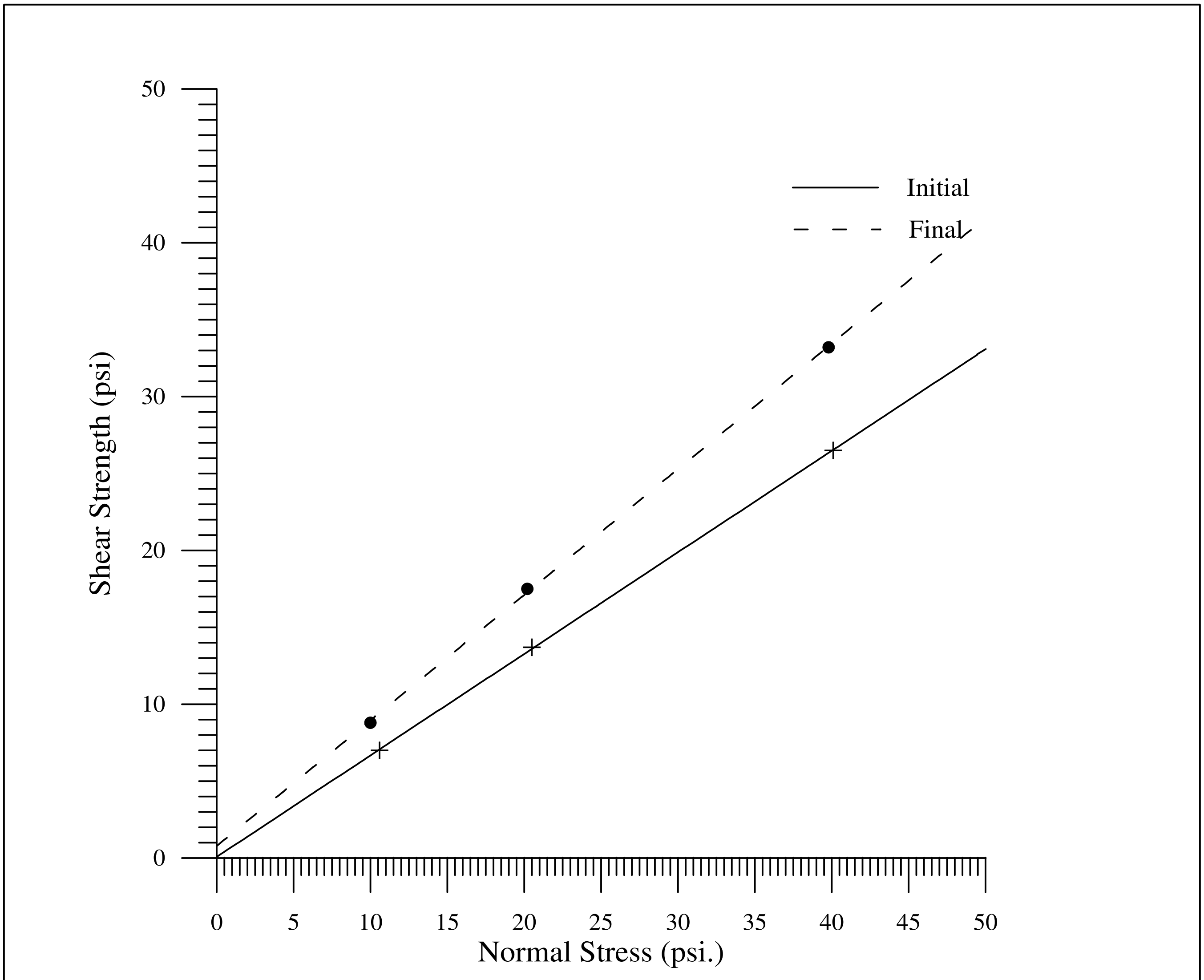
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 21, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 103A
Boring: RKS-30-07
Depth: 55.1-55.6'

DESCRIPTION

Saw-cut interface in medium blue gray meta welded lapilli tuff.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	0.1	33.4
Final	0.8	39.2

Geo Test Unlimited GTU

27069 N. Bloomfield Rd.
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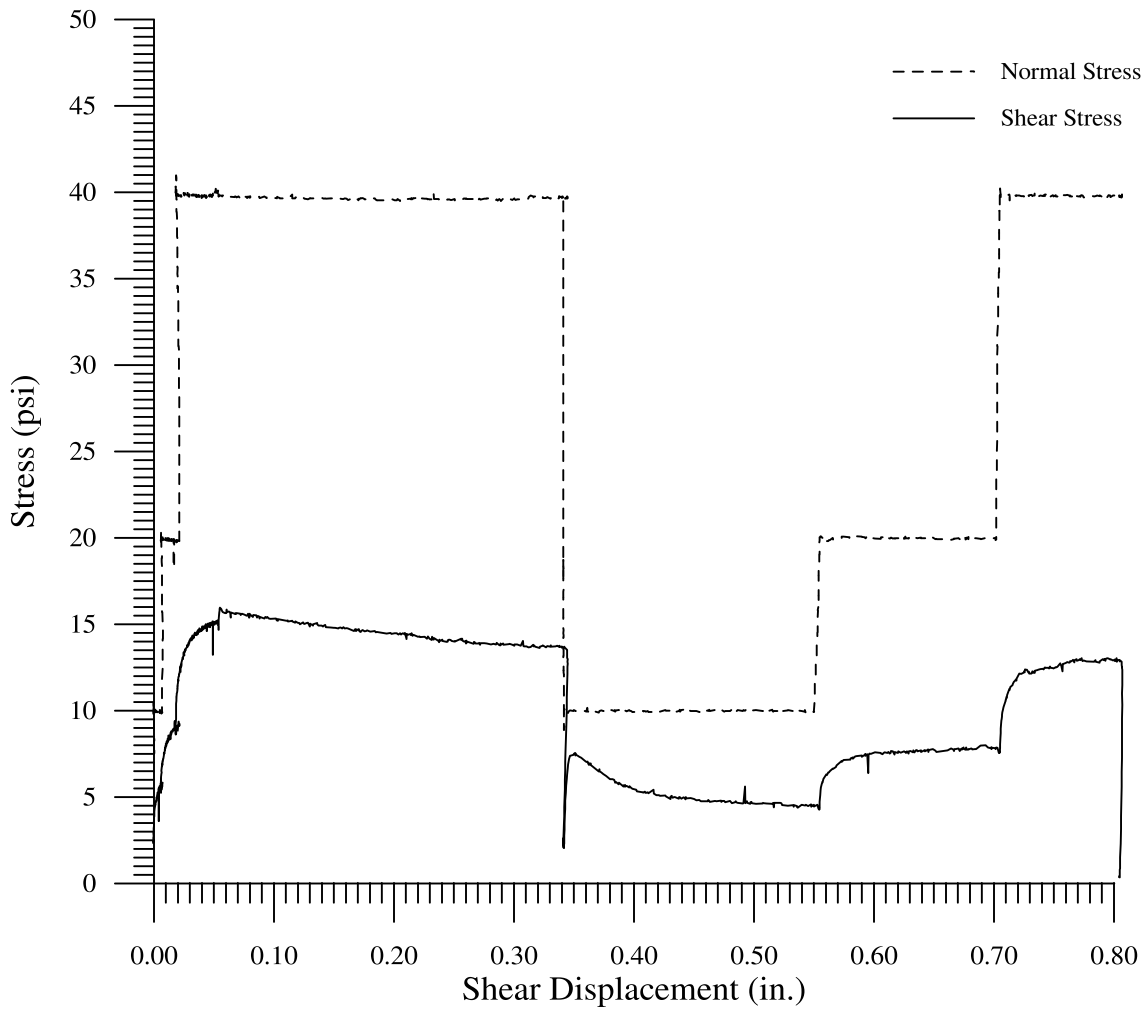
Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 21, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 104
Boring: SI-10-07
Depth: 43.4-44.0'

DESCRIPTION

Planar clay filled joint in fractured blue gray meta welded lapilli tuff. Light bluish white filling 1/4-5/8" thick with rock fragments.

	Normal Stress (psi)	Shear Strength (psi)
Initial	9.8	6.0
	19.8	9.5
	39.8	15.2
Final	10.0	4.5
	19.8	7.8
	39.8	13.0

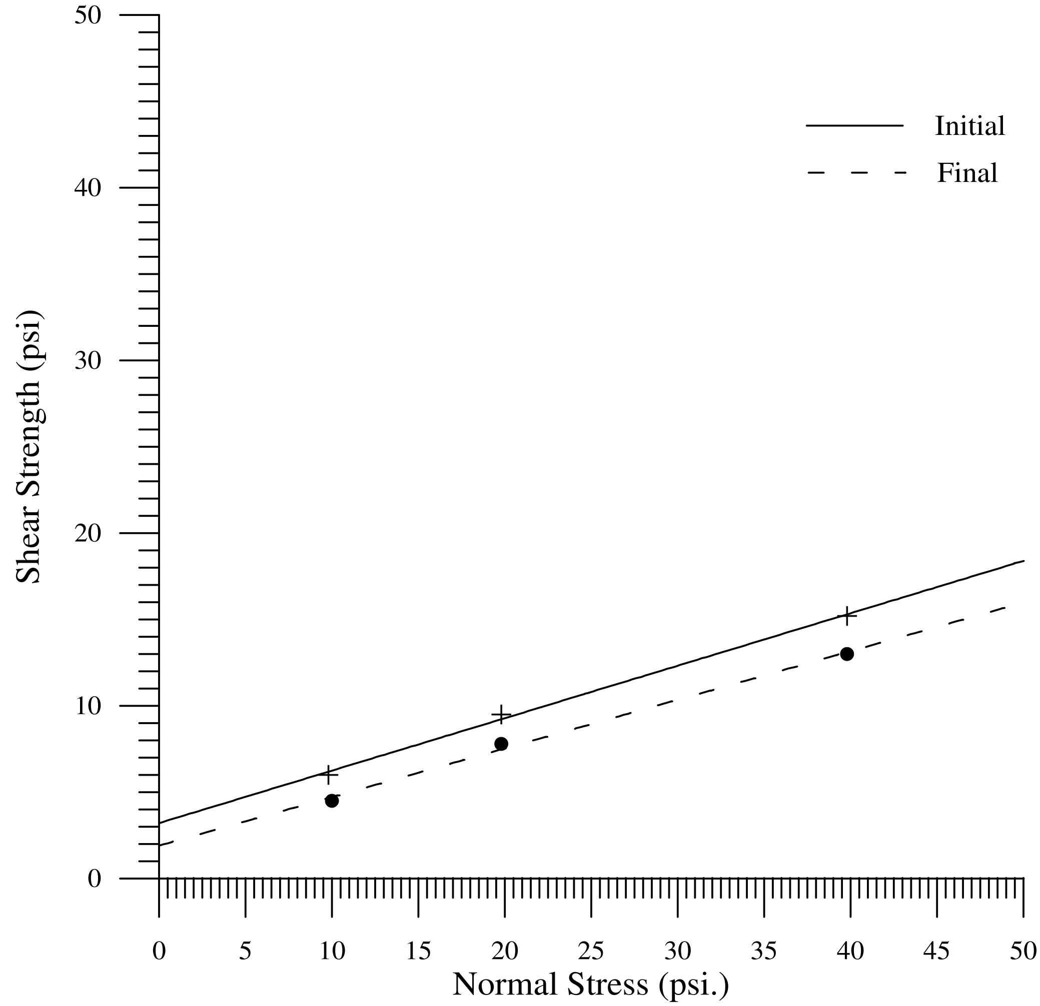
Geo Test Unlimited (GTU)
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 22, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 104
Boring: SI-10-07
Depth: 43.4-44.0'

DESCRIPTION

Planar clay filled joint in fractured blue gray meta welded lapilli tuff. Light bluish white filling 1/4-5/8" thick with rock fragments.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	3.2	16.9
Final	1.9	15.7

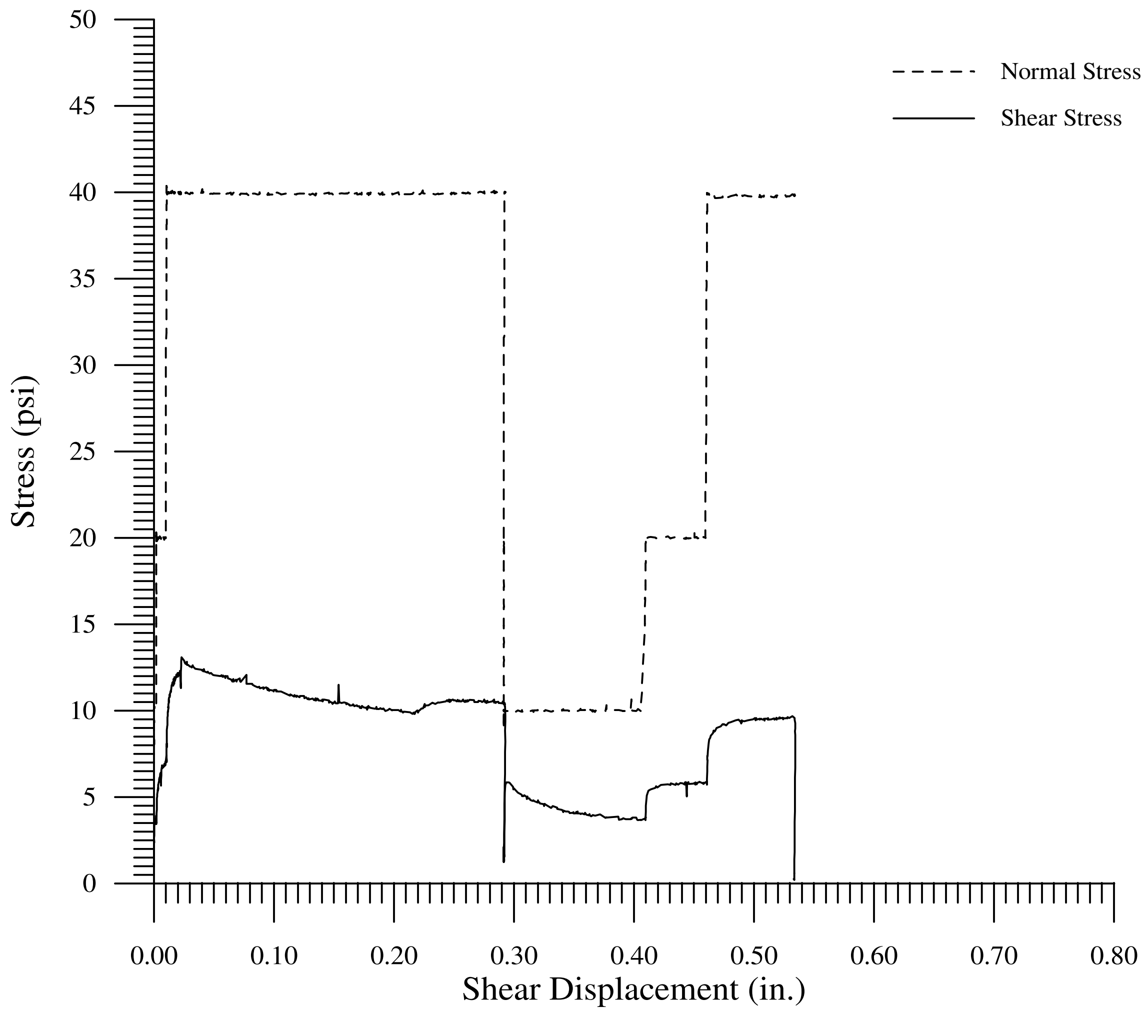
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 22, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 102A
Boring: SI-2-07
Depth: 40.4-41.4'

DESCRIPTION

Fairly planar clay filled joint in medium gray and brownish gray meta welded lapilli tuff. Light yellowish brown filling about 1/8" thick.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.1	3.7
	20.0	7.0
	40.0	12.2
Final	10.0	3.6
	20.0	5.8
	39.8	9.5

Geo Test Unlimited (GTU)
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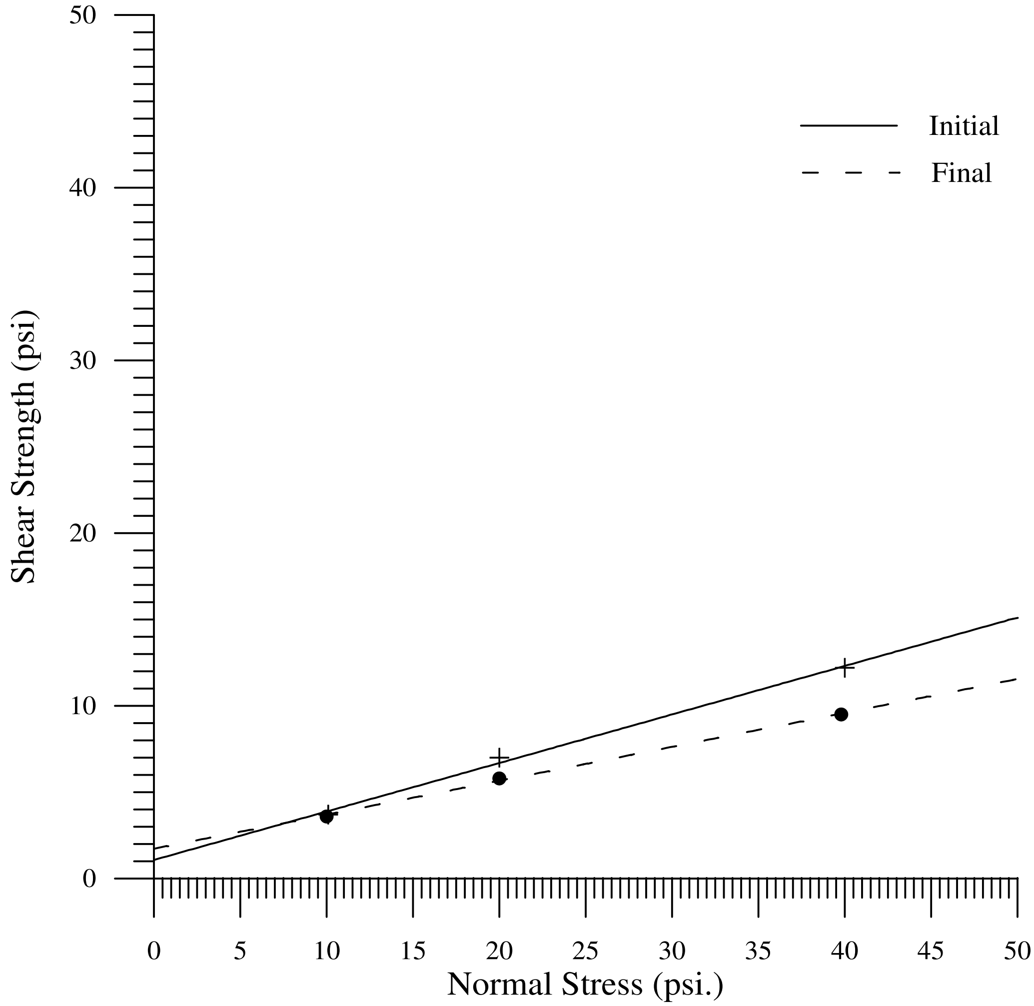
Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 22, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 102A
Boring: SI-2-07
Depth: 40.4-41.4'

DESCRIPTION

Fairly planar clay filled joint in medium gray and brownish gray meta welded lapilli tuff. Light yellowish brown filling about 1/8" thick.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	1.1	15.7
Final	1.7	11.1

Geo Test Unlimited GTU
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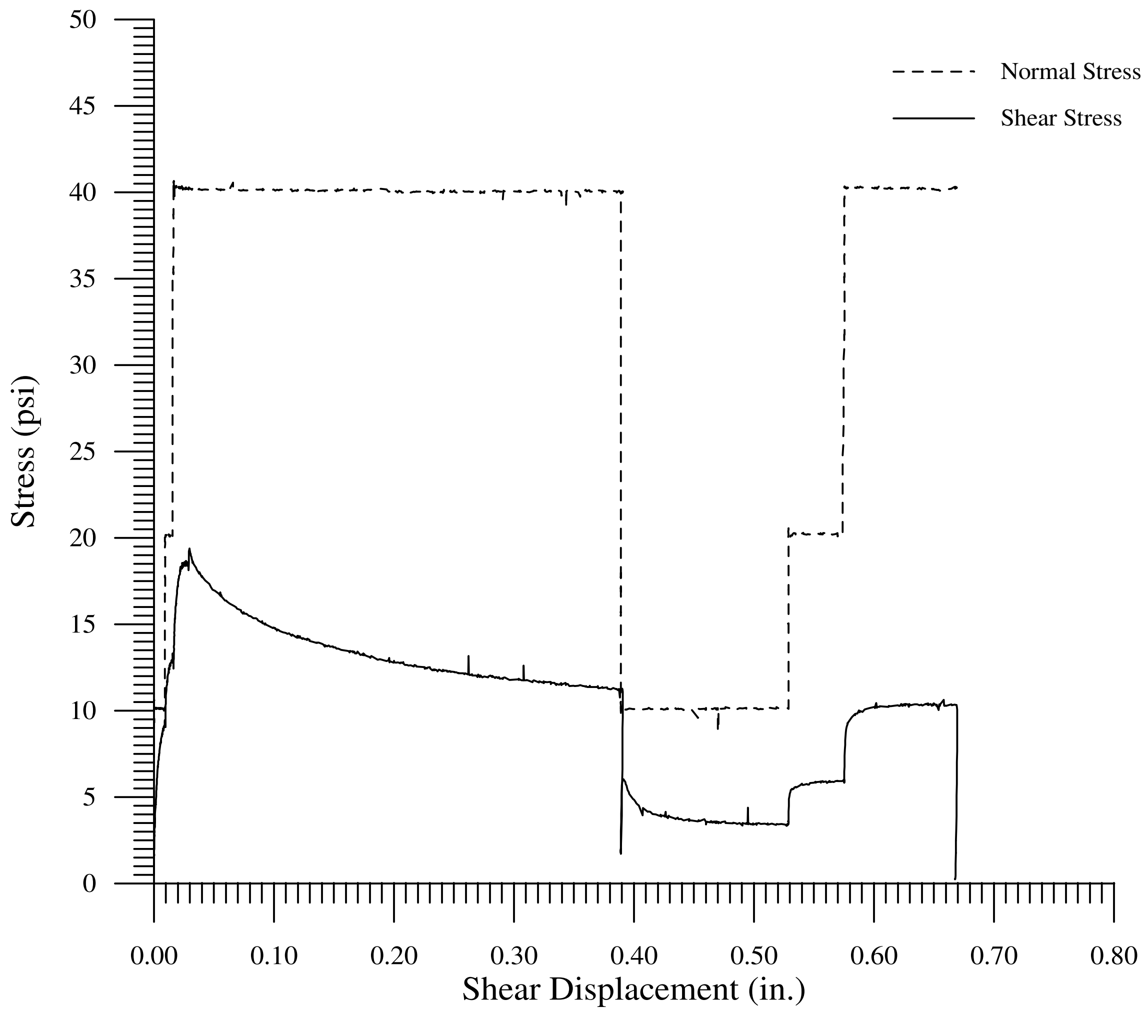
Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 22, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 105
Boring: SI-2-07
Depth: 84.6-86.0'

DESCRIPTION

Planar clay filled joint in blue gray meta welded lapilli tuff. White filling with light brown interlacings about 1/8-3/8" thick.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.1	9.4
	20.1	13.0
	40.1	18.5
Final	10.1	3.4
	20.2	6.0
	40.2	10.4

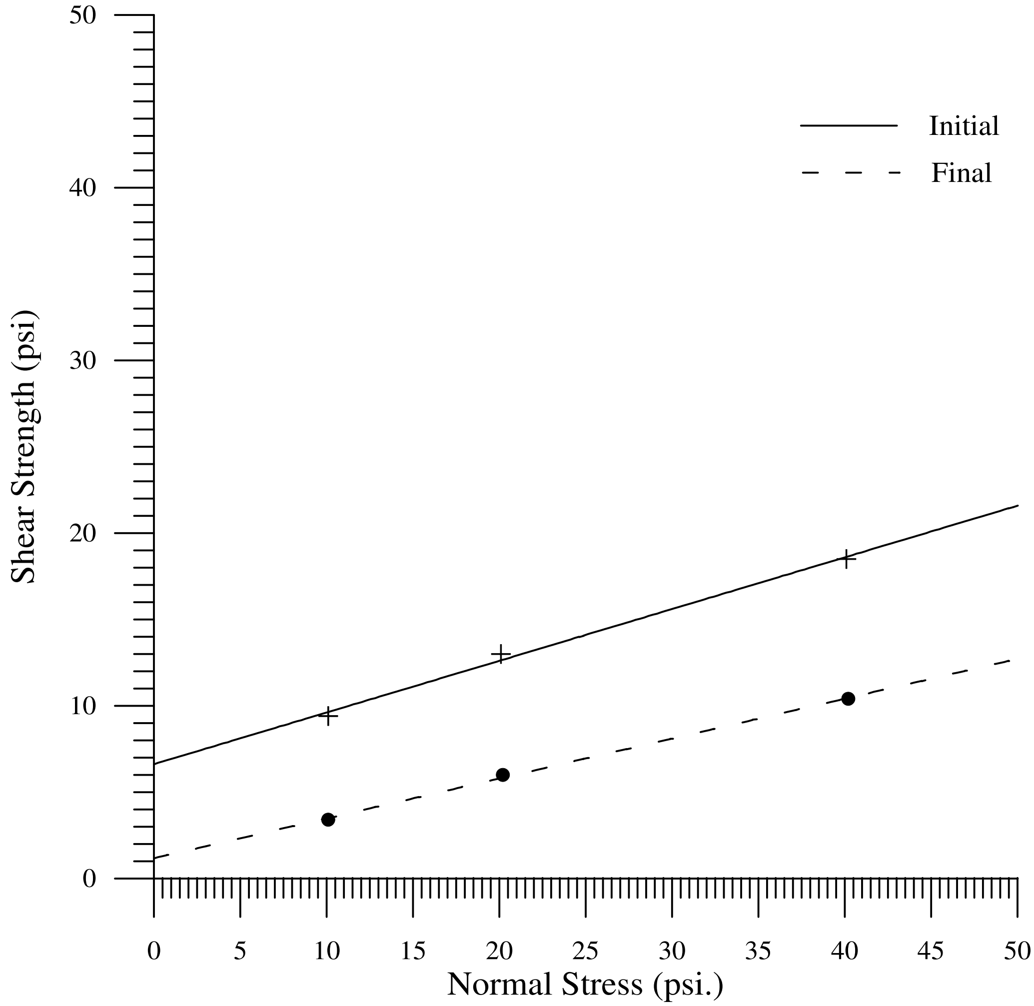
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 22, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 105
Boring: SI-2-07
Depth: 84.6-86.0'

DESCRIPTION

Planar clay filled joint in blue gray meta welded lapilli tuff. White filling with light brown interlacings about 1/8-3/8" thick.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	6.6	16.7
Final	1.2	13.0

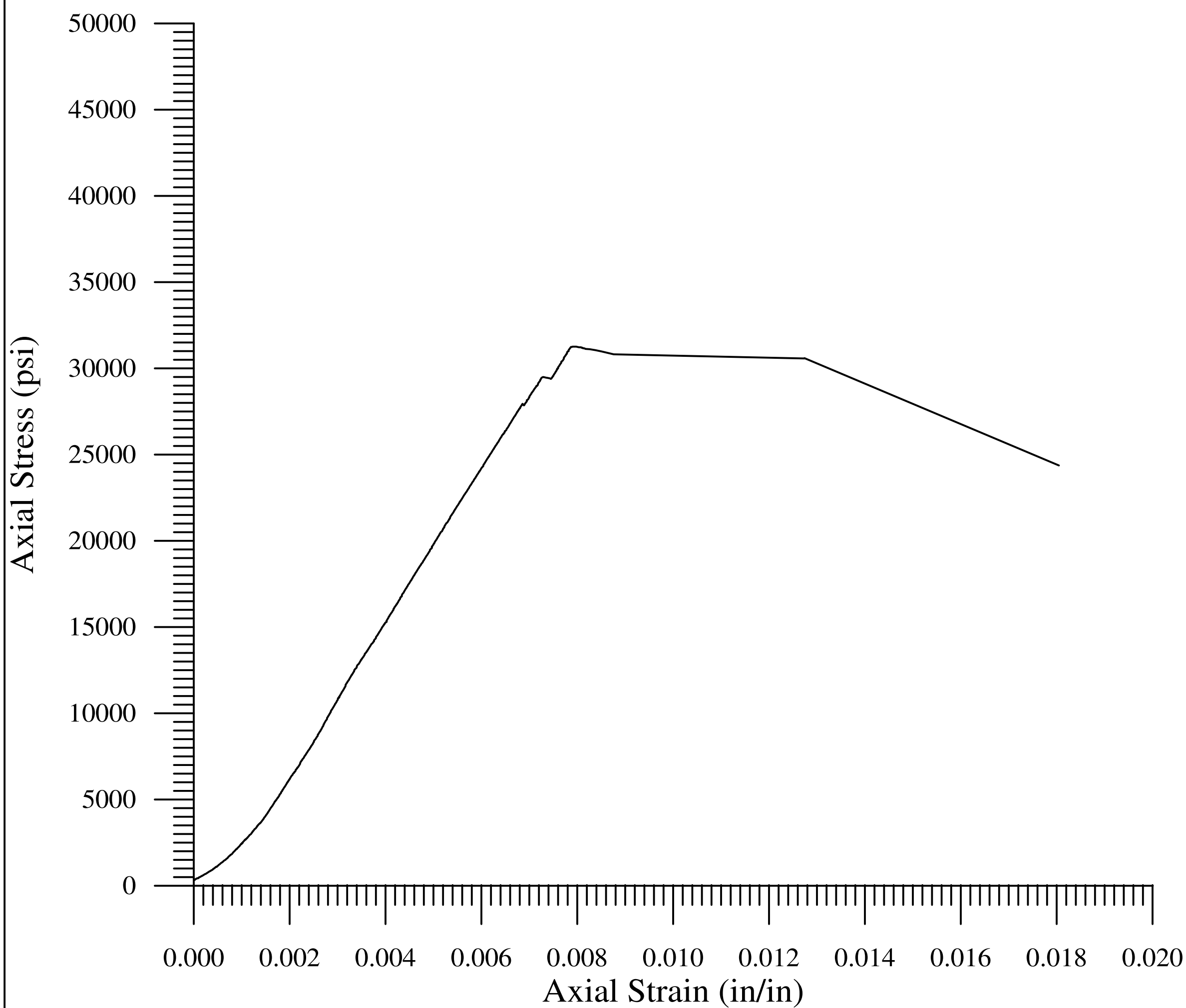
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 03-2007

Test Date: **January 22, 2008**



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101B
Boring: RKS-12-07
Depth: 29.5-30.3'

DESCRIPTION

Medium blue gray meta welded lapilli tuff, with a few light green zones in the matrix, with no apparent planes of weakness.

Density: 164.0 pcf
Strength: 31,257 psi

Geo Test Unlimited GTU

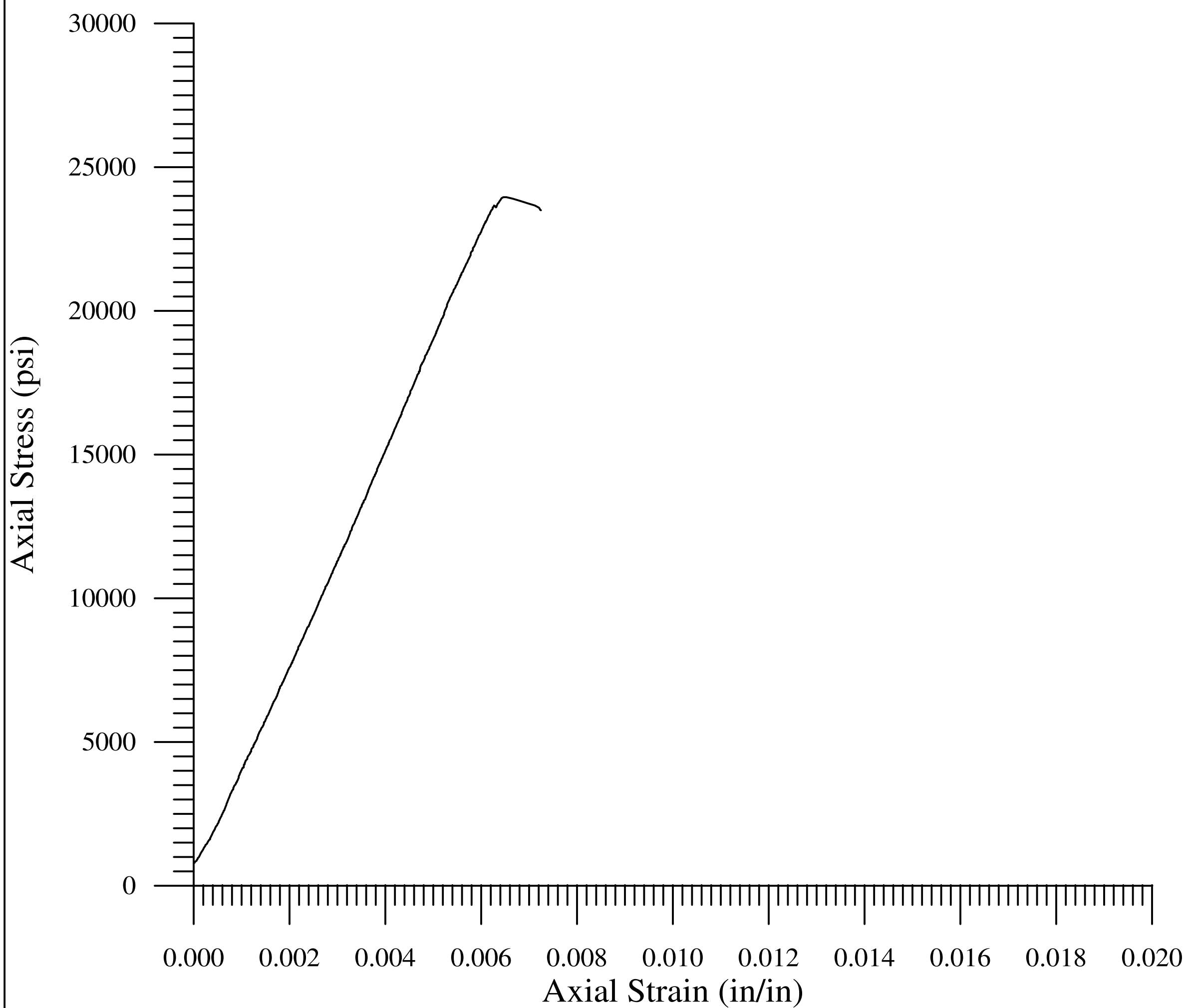
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 103B
Boring: RKS-12-07
Depth: 124.6-125.3'

DESCRIPTION

Medium blue gray meta welded lapilli tuff, with an axial healed hairline joint.

Density: 164.3 pcf
Strength: 23,952 psi

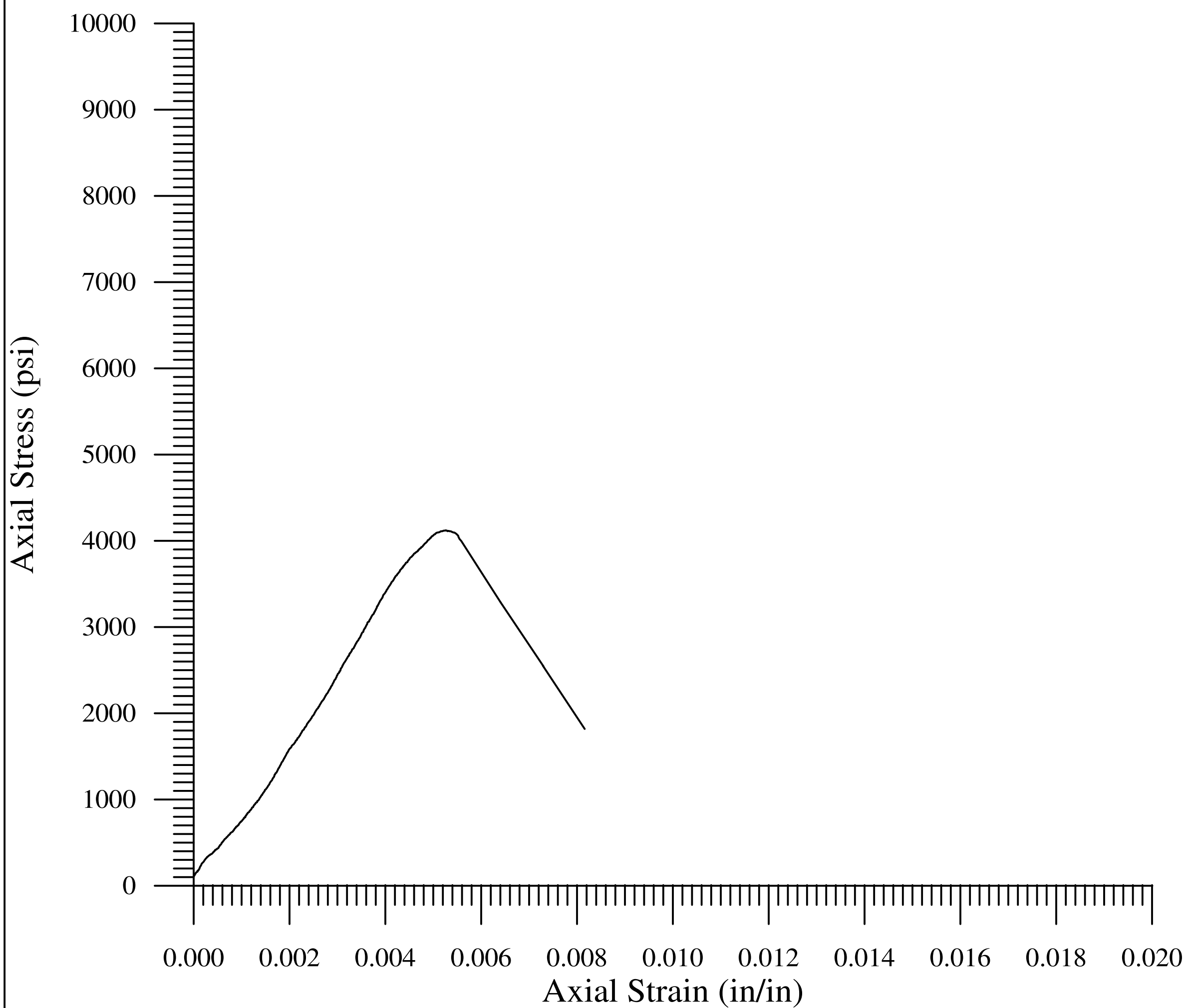
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102
Boring: RKS-13-07
Depth: 19.0-19.7'

DESCRIPTION

Medium brown meta welded lapilli tuff, somewhat altered with zones of lighter brown more severely altered matrix.

Density: 155.7 pcf
Strength: 4120 psi

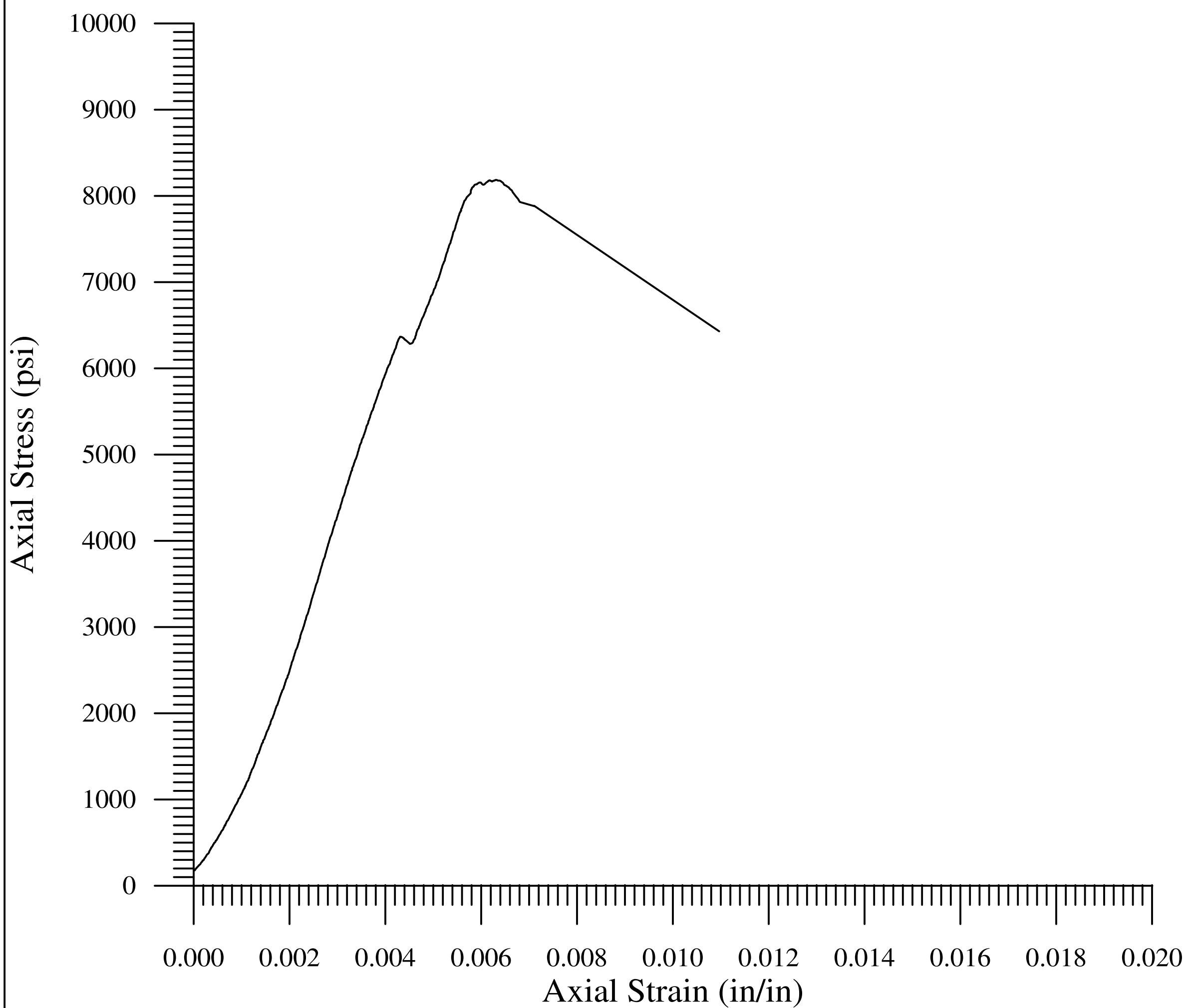
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 104A
Boring: RKS-13-07
Depth: 44.1-44.6'

DESCRIPTION

Light greenish gray meta welded lapilli tuff, slightly altered with light green more altered inclusions with no apparent planes of weakness.

Density: 162.6 pcf
Strength: 8184 psi

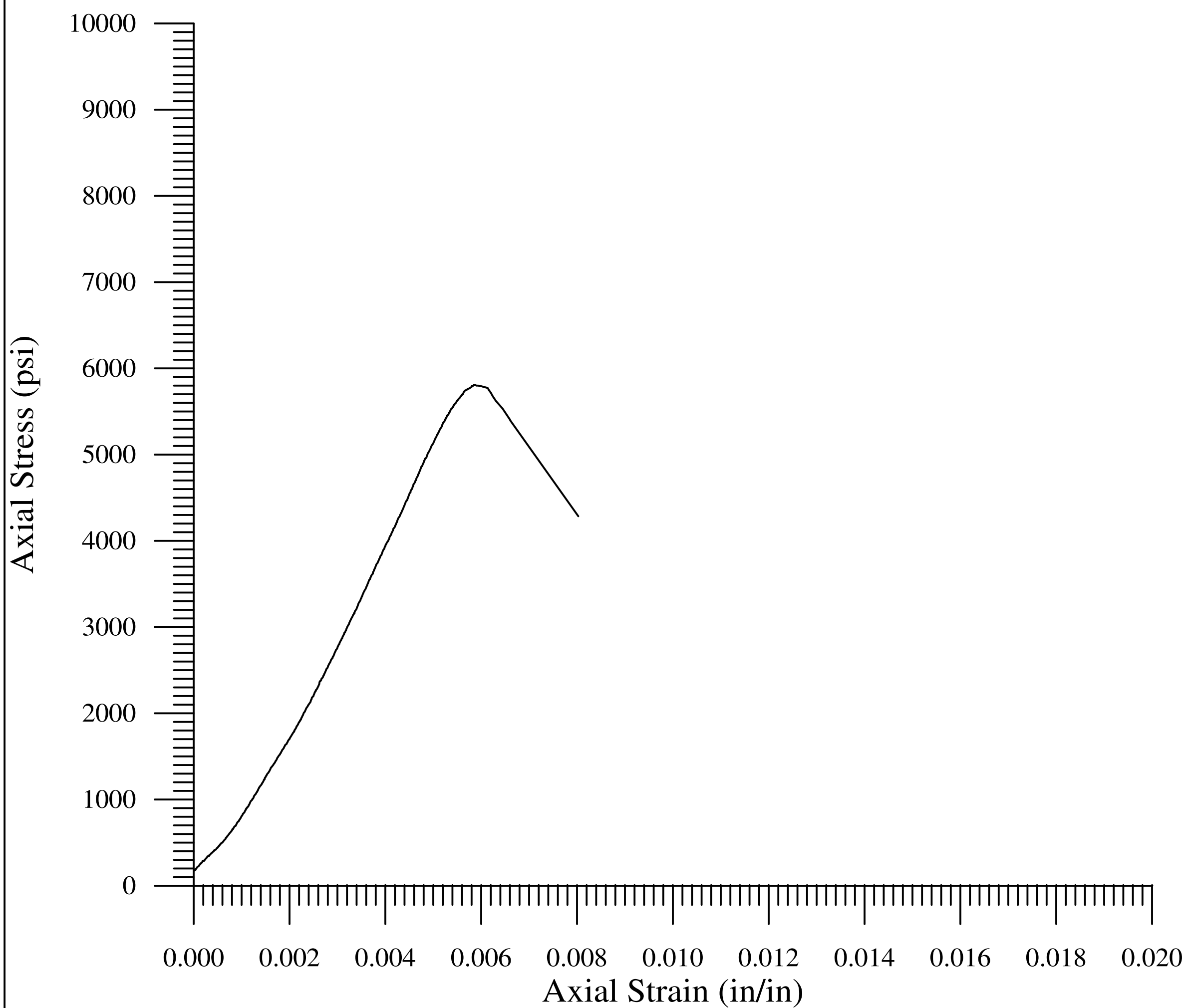
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 103B
Boring: RKS-14-07
Depth: 78.8-79.4'

DESCRIPTION

Light greenish gray meta welded lapilli tuff, slightly altered with light green more altered inclusions with one minor end fracture.

Density: 159.0 pcf
Strength: 5805 psi

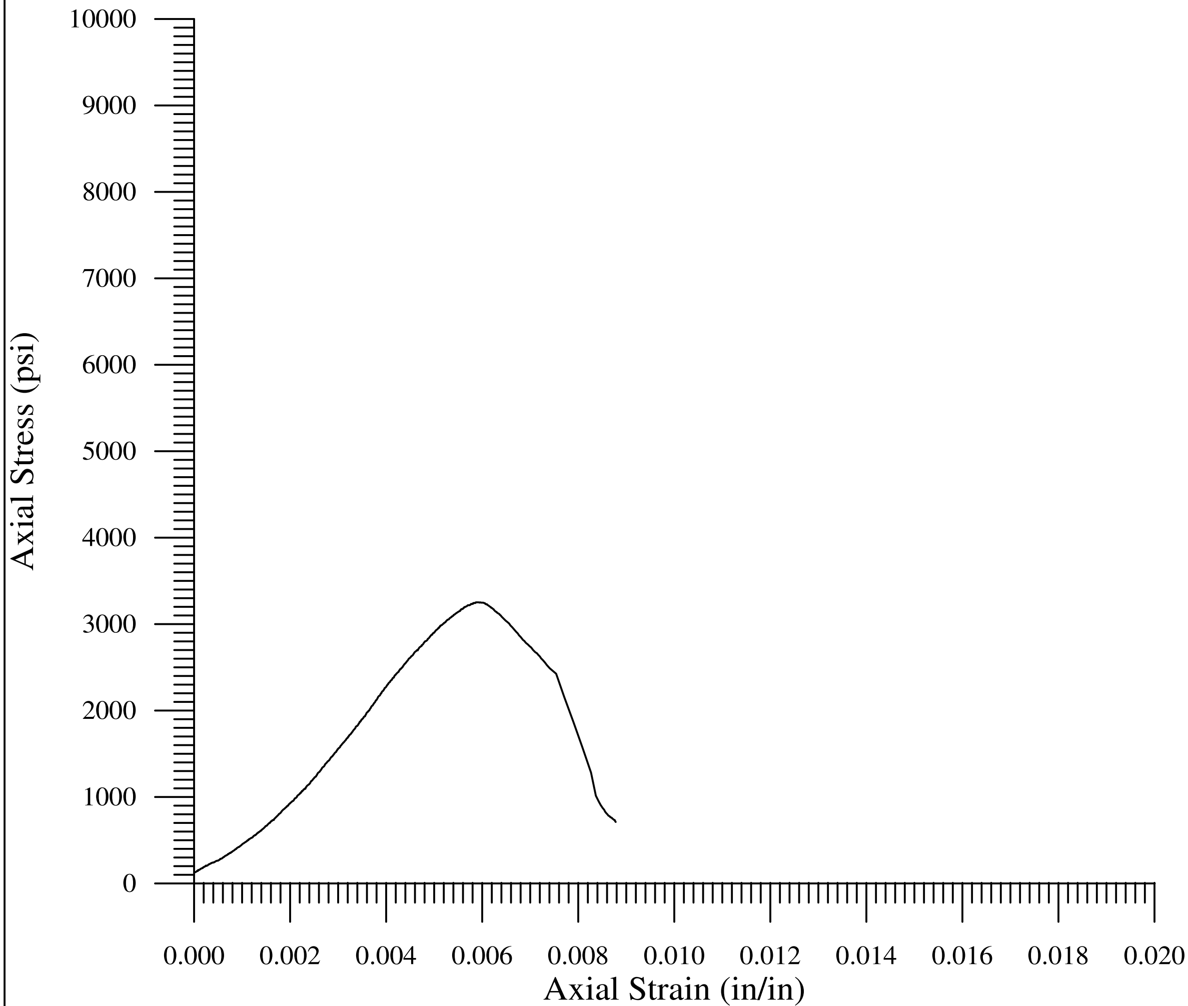
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102B
Boring: RKS-15-07
Depth: 21.1-21.8'

DESCRIPTION

Medium brown meta welded lapilli tuff, altered with weak end fractures that have been glued.

Density: 151.6 pcf
Strength: 3250 psi

Geo Test Unlimited *GTU*

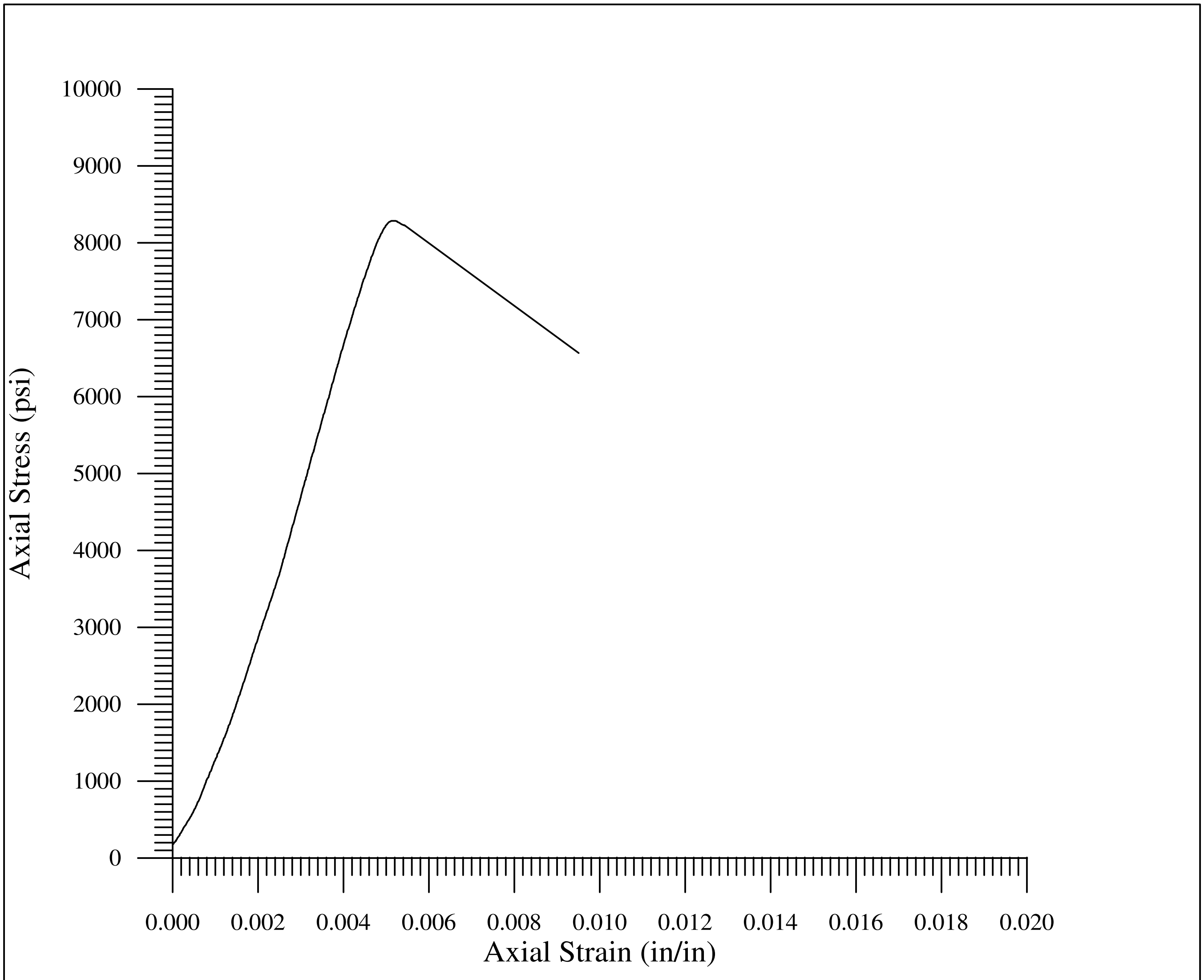
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 105A
Boring: RKS-15-07
Depth: 120.0-120.5'

DESCRIPTION

Medium brown meta welded lapilli tuff, altered with a few thin planar zones of weakness.

Density: 159.6 pcf
Strength: 8287 psi

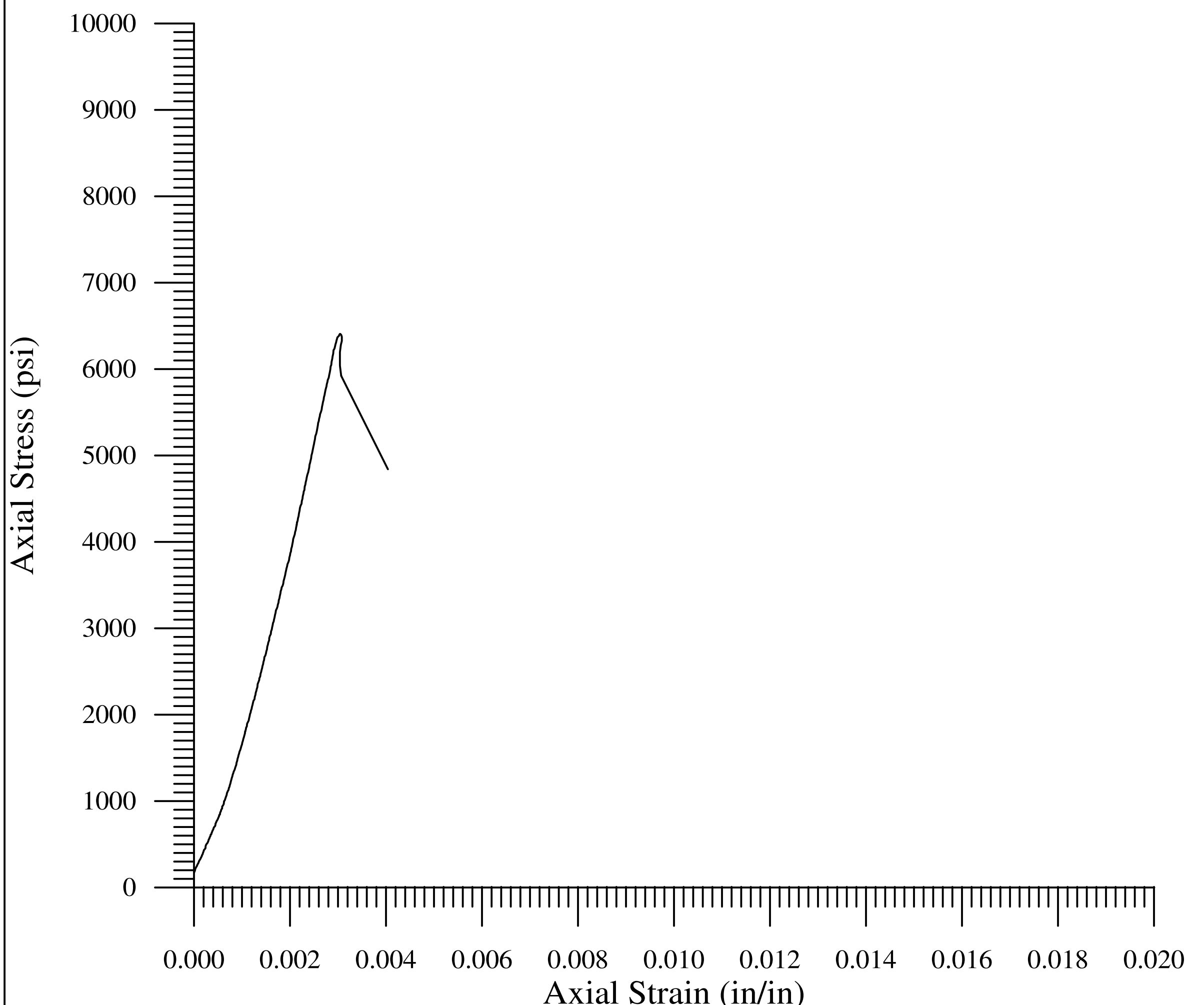
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101B
Boring: RKS-16-07
Depth: 47.6-48.2'

DESCRIPTION

Medium brown meta welded lapilli tuff, oxide stained with a small light gray clay(?) zone and one non-through-going fracture.

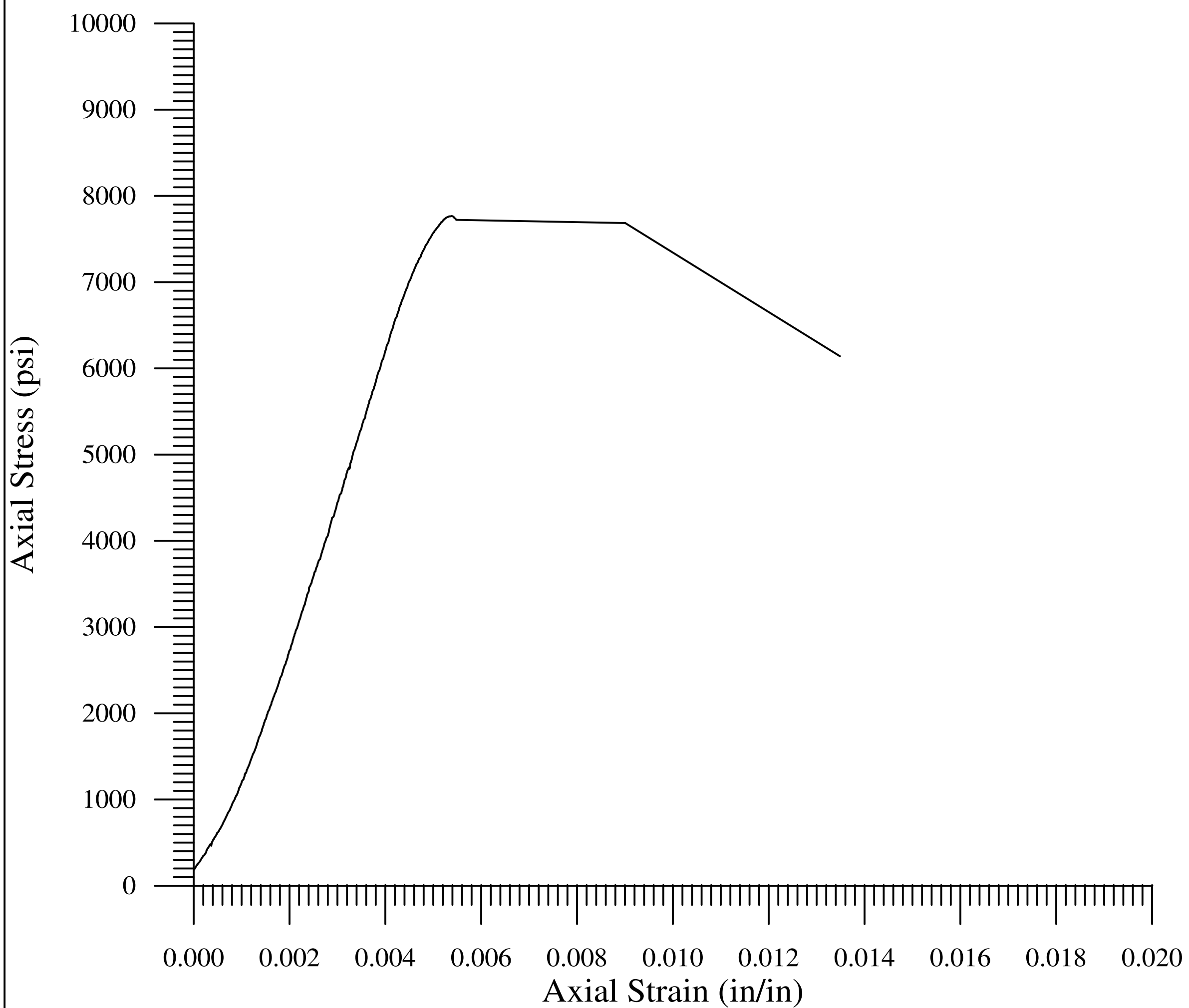
Density: 159.3 pcf
Strength: 6408 psi

Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment
Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102
Boring: RKS-17-07
Depth: 53.3-54.0'

DESCRIPTION

Meta welded lapilli tuff, medium brown and blue gray clasts in a light gray matrix, with a few non-through-going fractures.

Density: 156.2 pcf
Strength: 7767 psi

Geo Test Unlimited

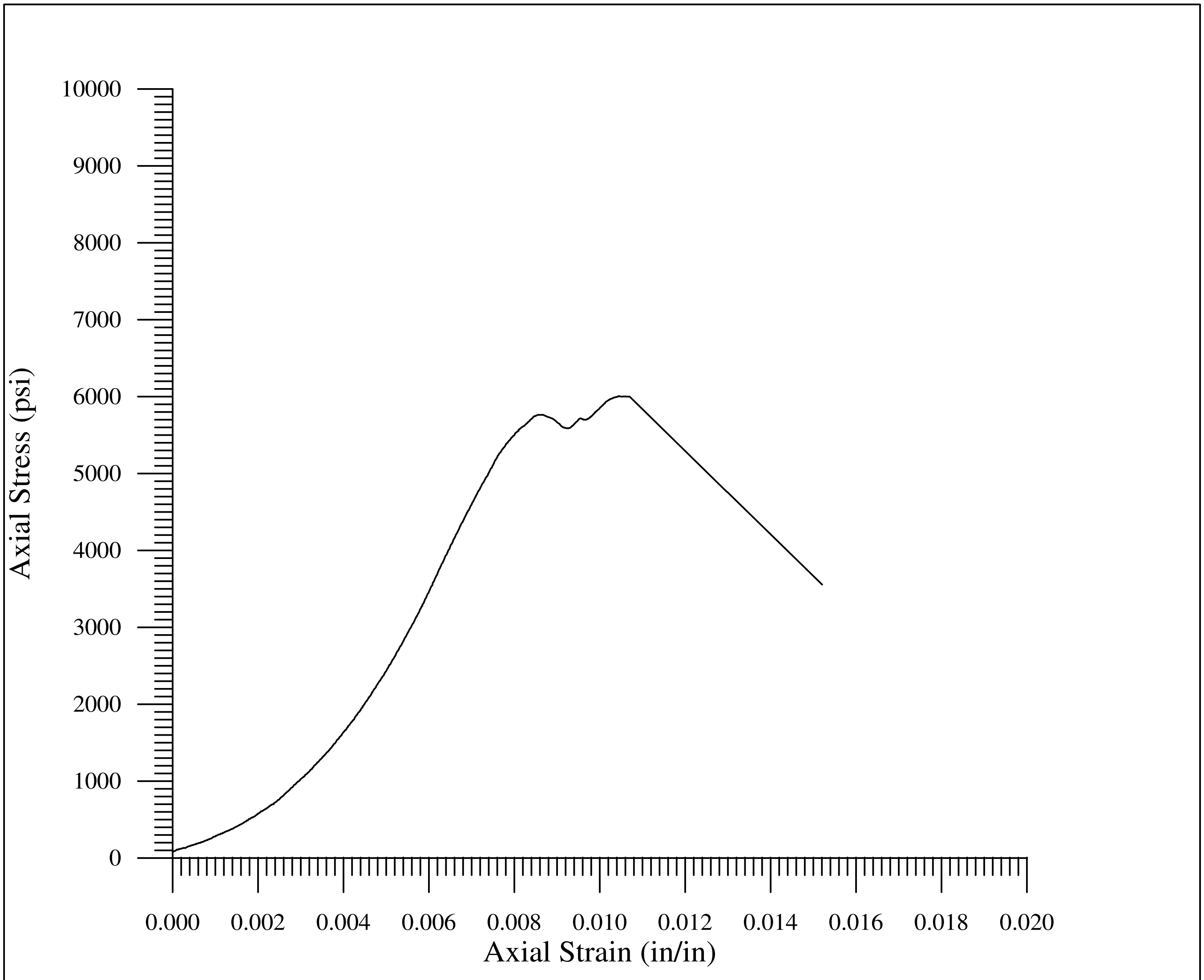
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102B
Boring: RKS-18-07
Depth: 72.5-72.9'

DESCRIPTION

Dark gray meta welded lapilli tuff, heavily fractured.

Density: 159.4 pcf
Strength: 6005 psi

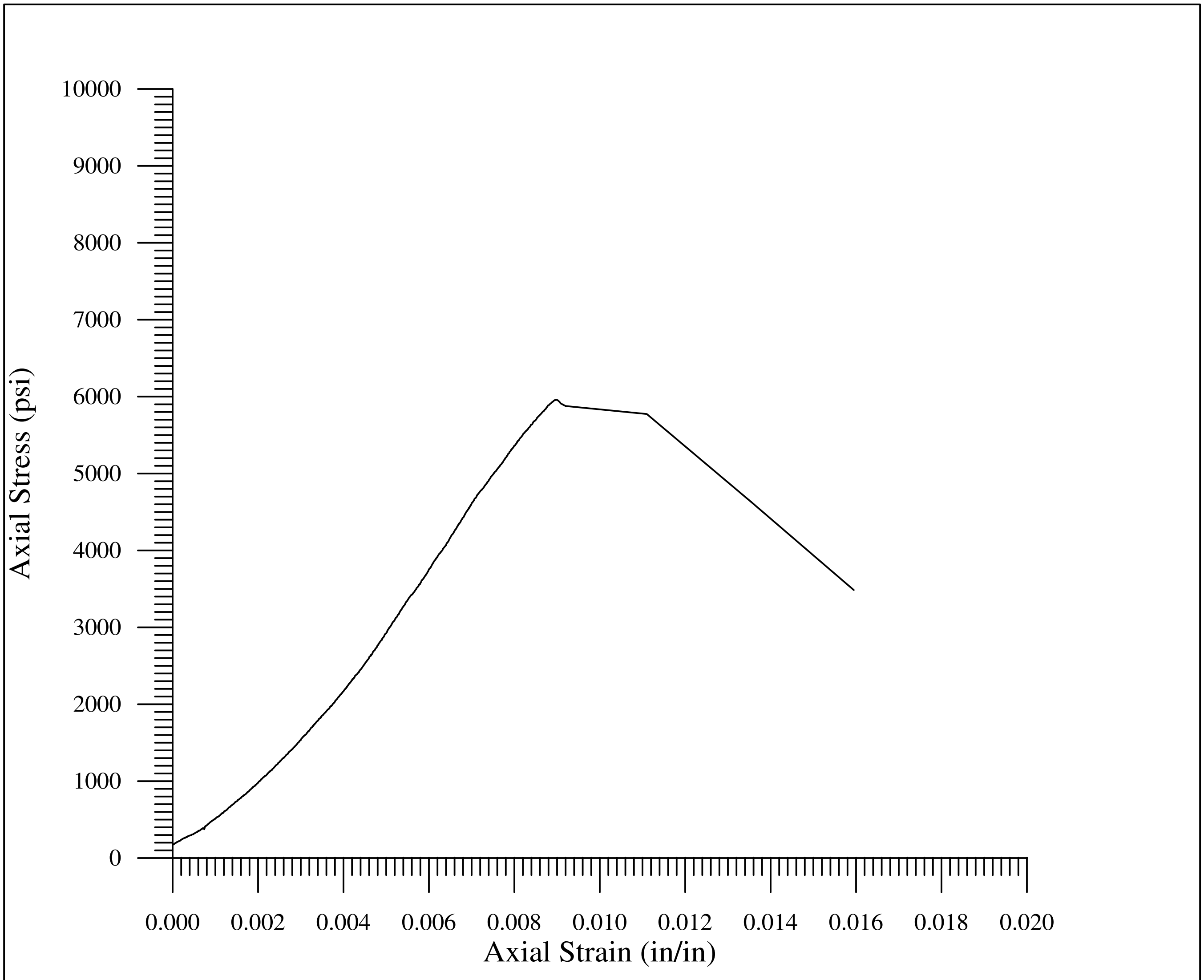
Geo Test Unlimited (GTU)
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102
Boring: RKS-19-07
Depth: 30.4-31.4'

DESCRIPTION

Light gray meta welded lapilli tuff, with several light blue inclusions altered to clay(?), with a glued end fracture.

Density: 156.4 pcf
Strength: 5959 psi

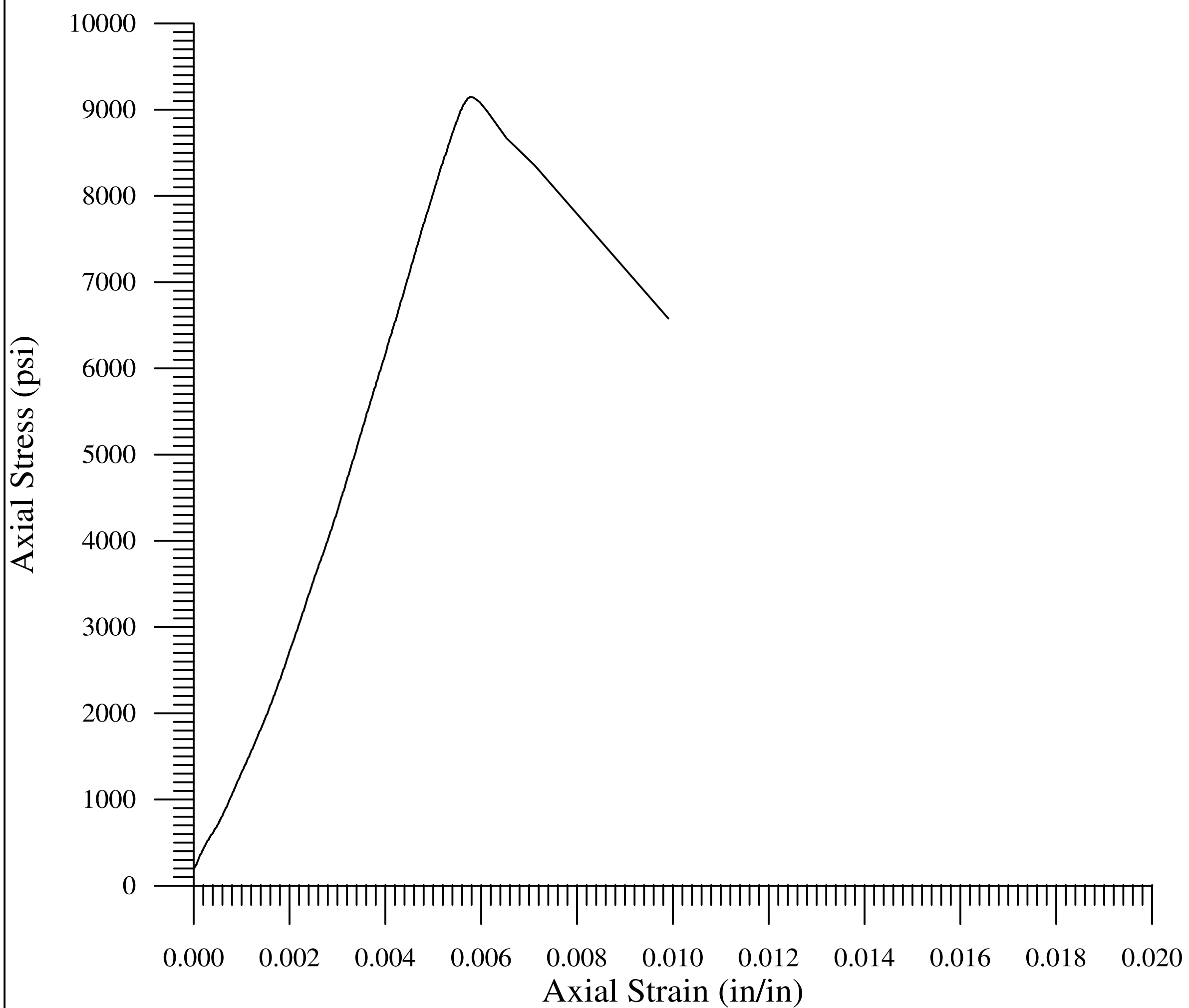
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 103B
Boring: RKS-19-07
Depth: 56.3-57.0'

DESCRIPTION

Light gray meta welded lapilli tuff,
with light blue inclusions altered to clay(?).

Density: 160.9 pcf
Strength: 9148 psi

Geo Test Unlimited GTU

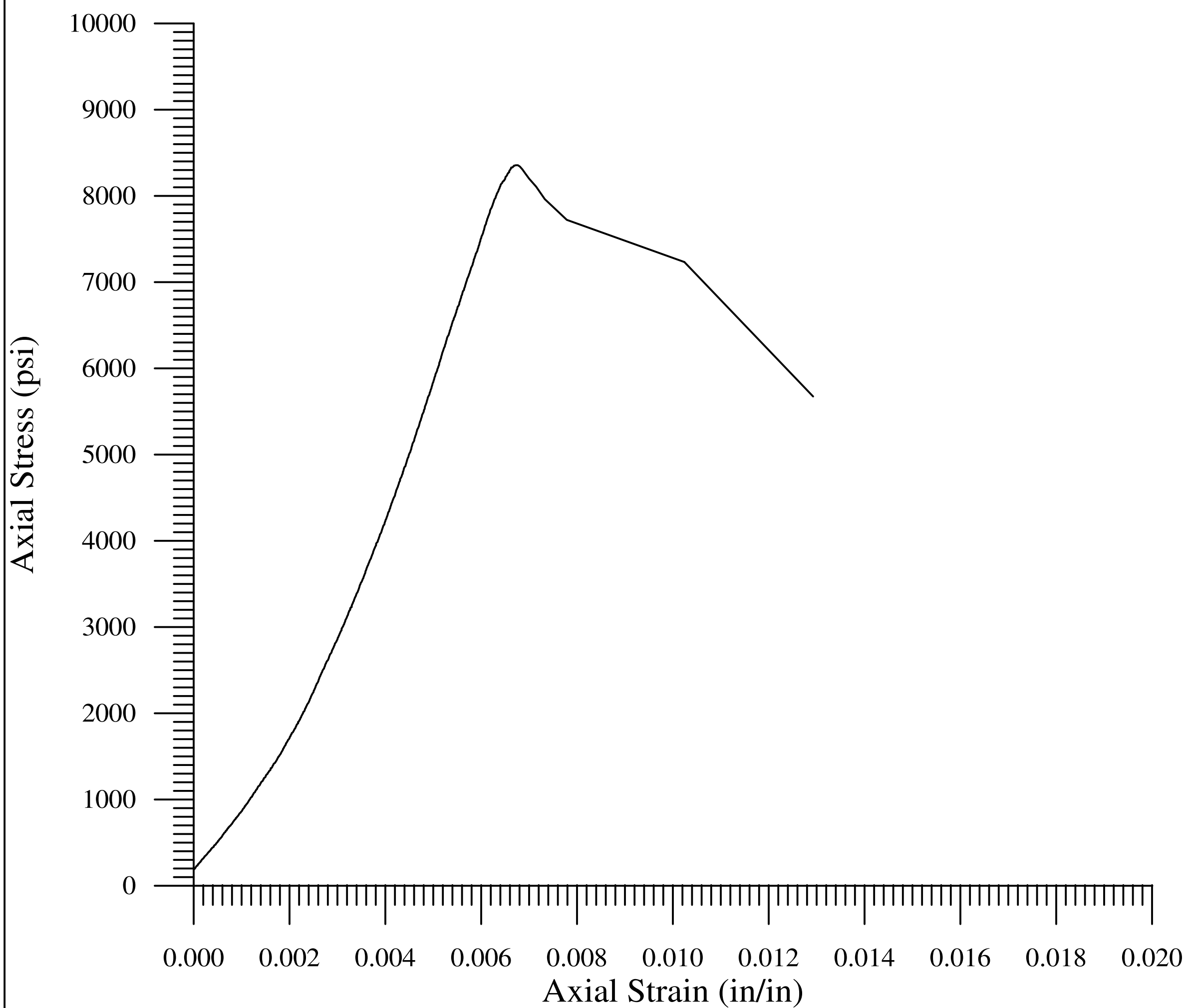
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102A
Boring: RKS-20-07
Depth: 64.8-65.4'

DESCRIPTION

Light gray meta welded lapilli tuff,
with light blue inclusions altered to clay(?).

Density: 160.4 pcf
Strength: 8358 psi

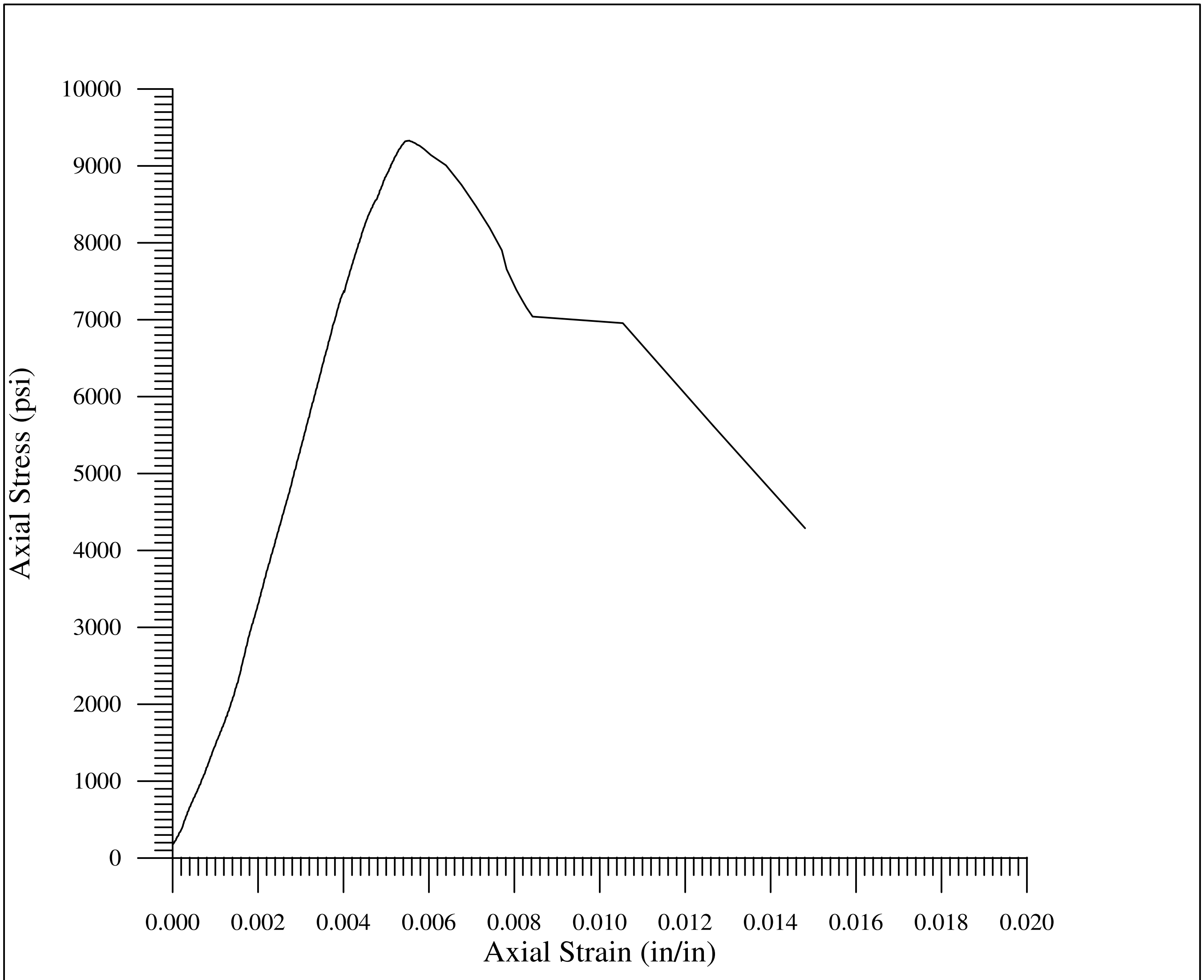
Geo Test Unlimited (GTU)
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101A
Boring: RKS-22-07
Depth: 11.7-12.5'

DESCRIPTION

Medium gray meta welded lapilli tuff, with a tight end fracture.

Density: 166.0 pcf
Strength: 9327 psi

Geo Test Unlimited GTU

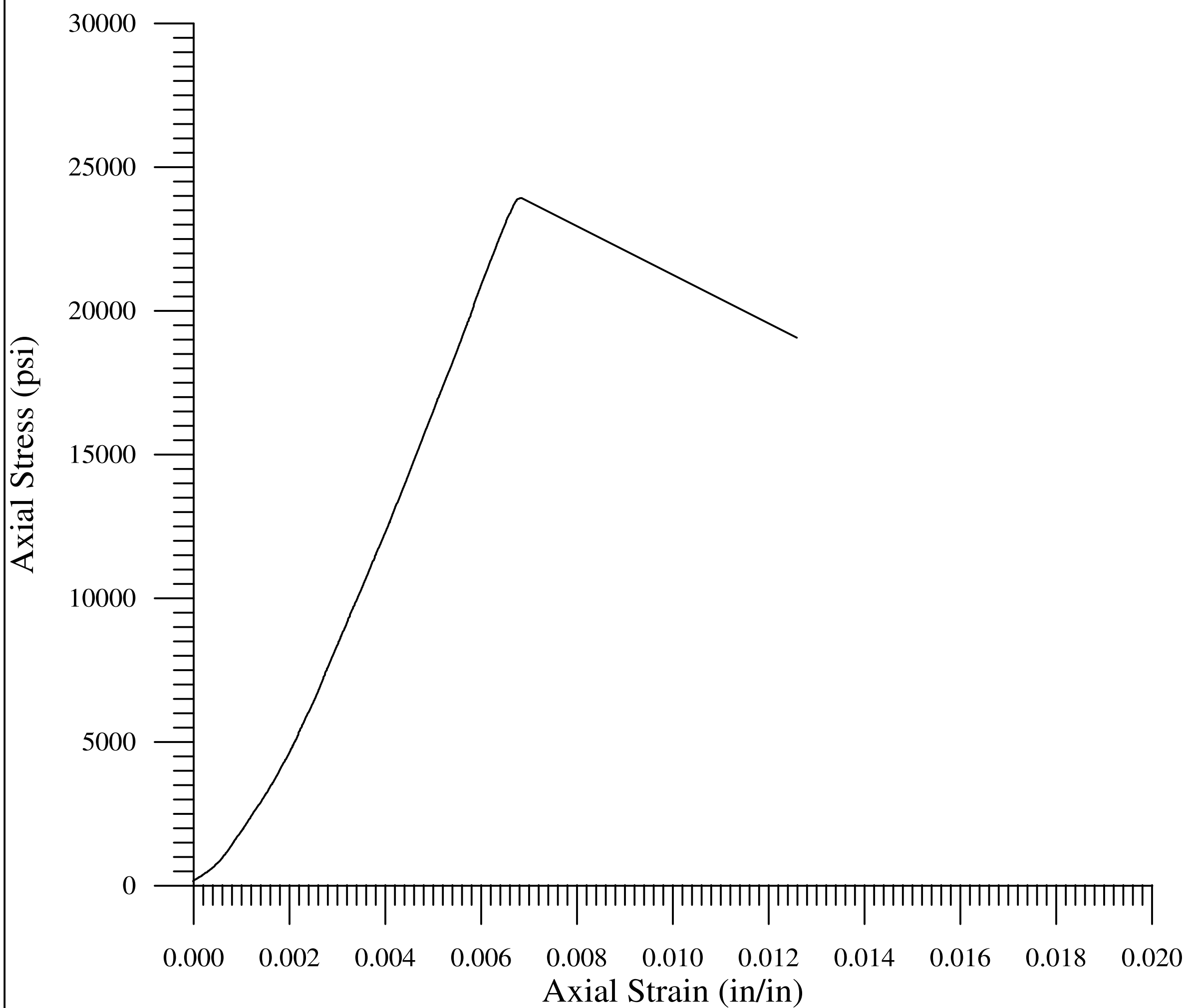
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101A
Boring: RKS-23-07
Depth: 10.3-11.0'

DESCRIPTION

Medium blue gray meta welded lapilli tuff, with no apparent planes of weakness

Density: 163.2 pcf
Strength: 23,917 psi

Geo Test Unlimited GTU

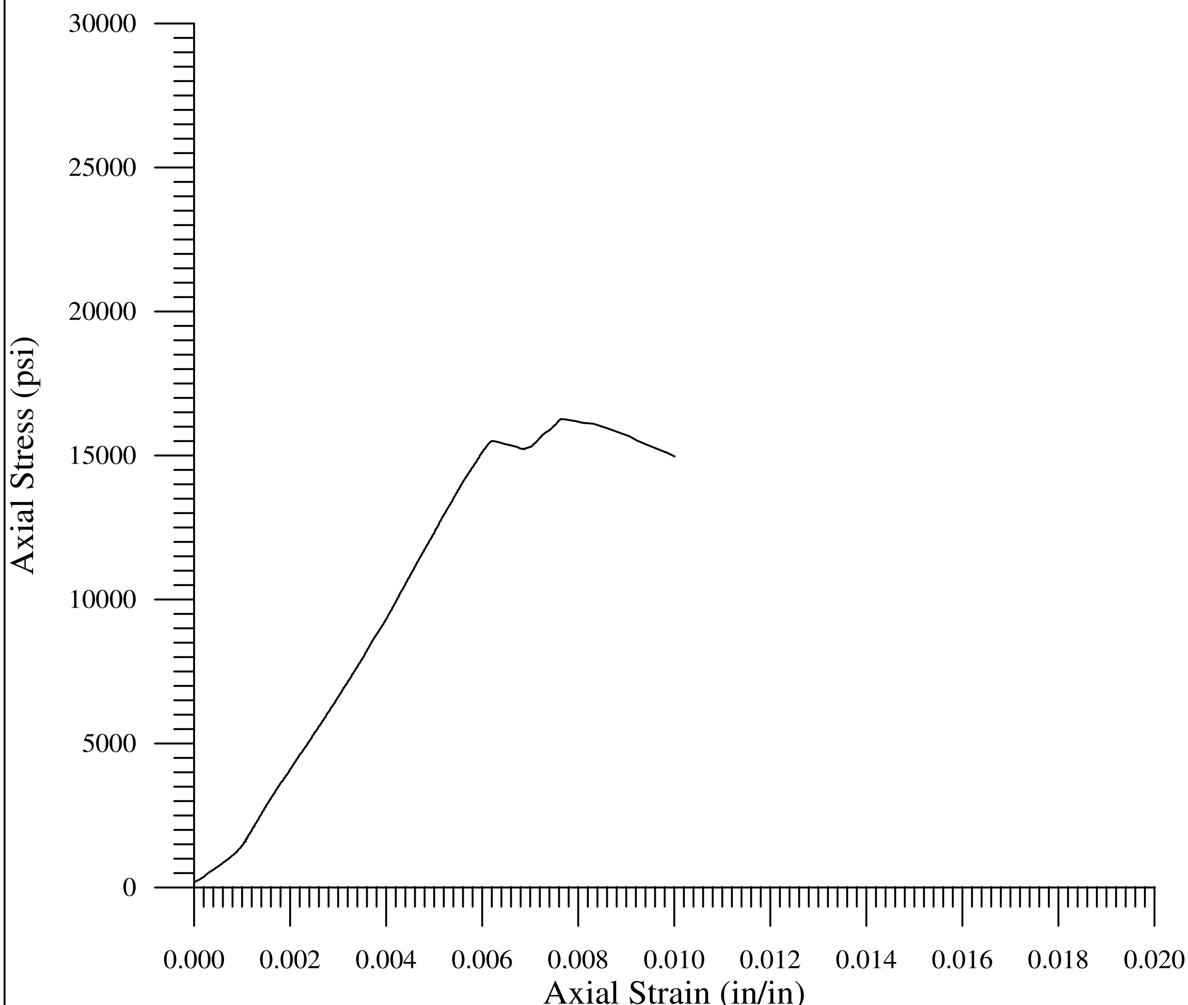
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101B
Boring: RKS-26-07
Depth: 32.1-32.8'

DESCRIPTION

Medium blue gray meta welded lapilli tuff, with no apparent planes of weakness

Density: 163.9 pcf
Strength: 16,267 psi

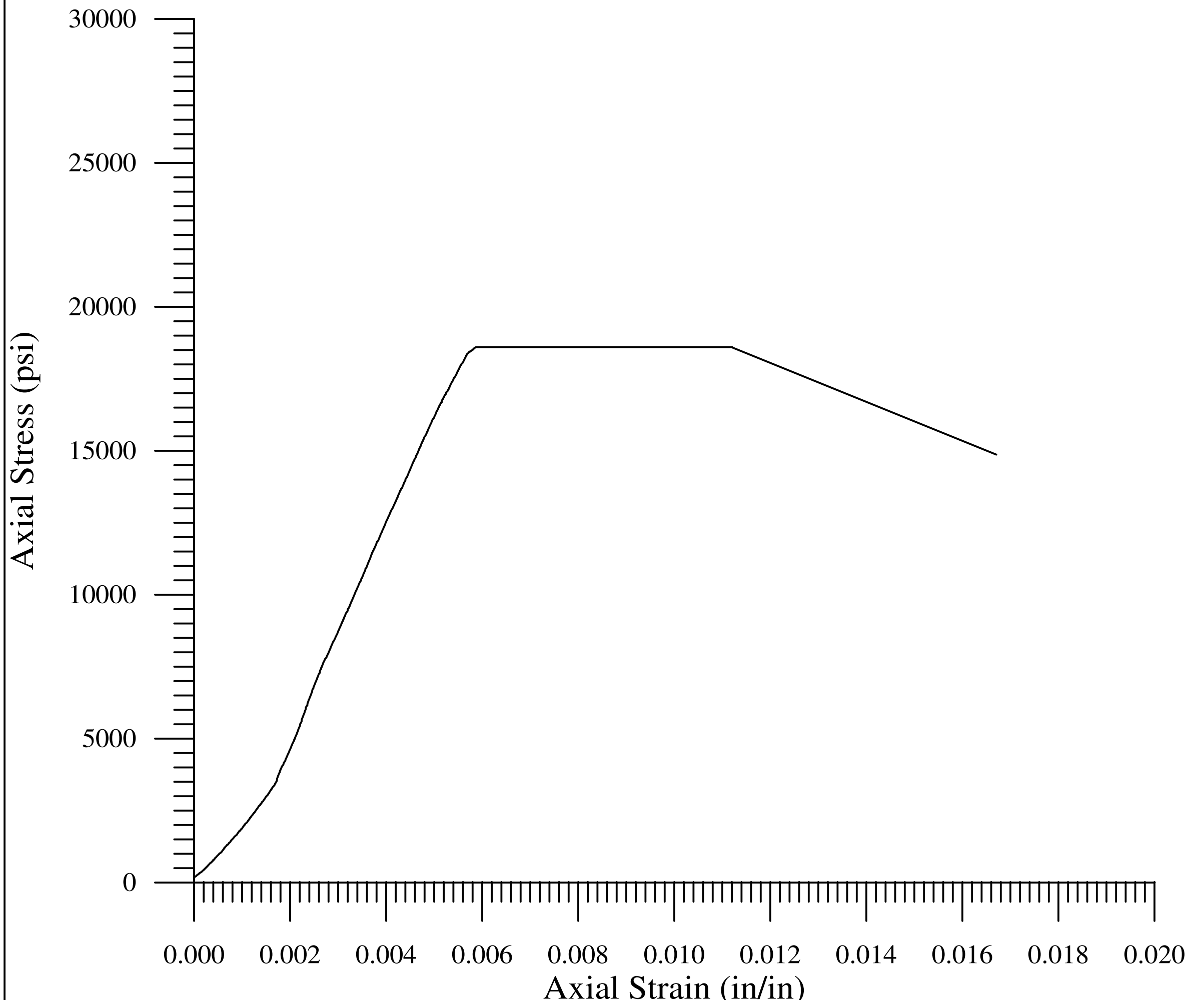
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102A
Boring: RKS-27-07
Depth: 28.5-29.2'

DESCRIPTION

Light to medium gray meta welded lapilli tuff, with a few altered clasts.

Density: 164.6 pcf
Strength: 18,597 psi

Geo Test Unlimited GTU

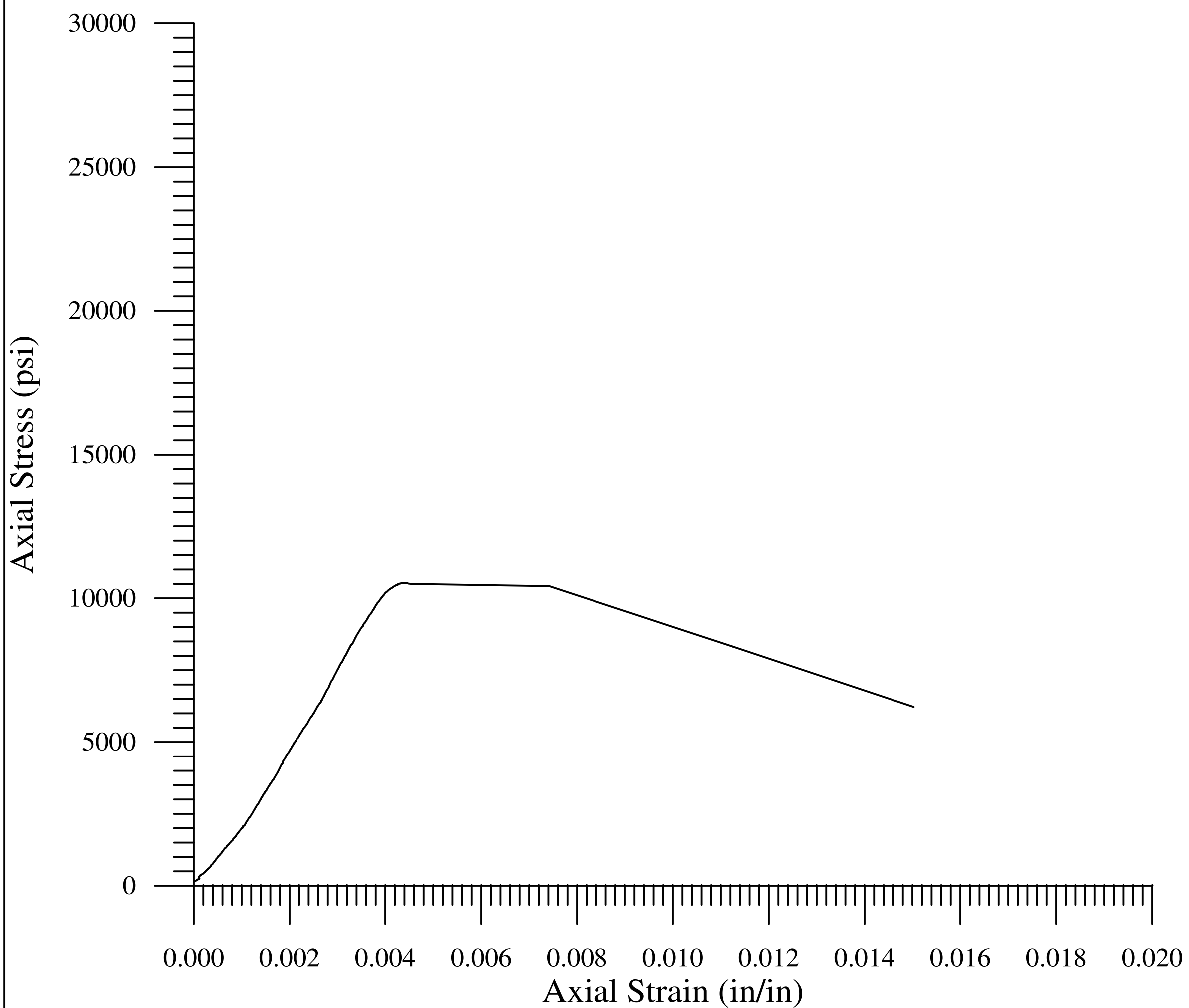
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102A
Boring: RKS-28-07
Depth: 65.4-66.0'

DESCRIPTION

Light gray meta welded lapilli tuff, with no apparent planes of weakness.

Density: 164.0 pcf
Strength: 10,535 psi

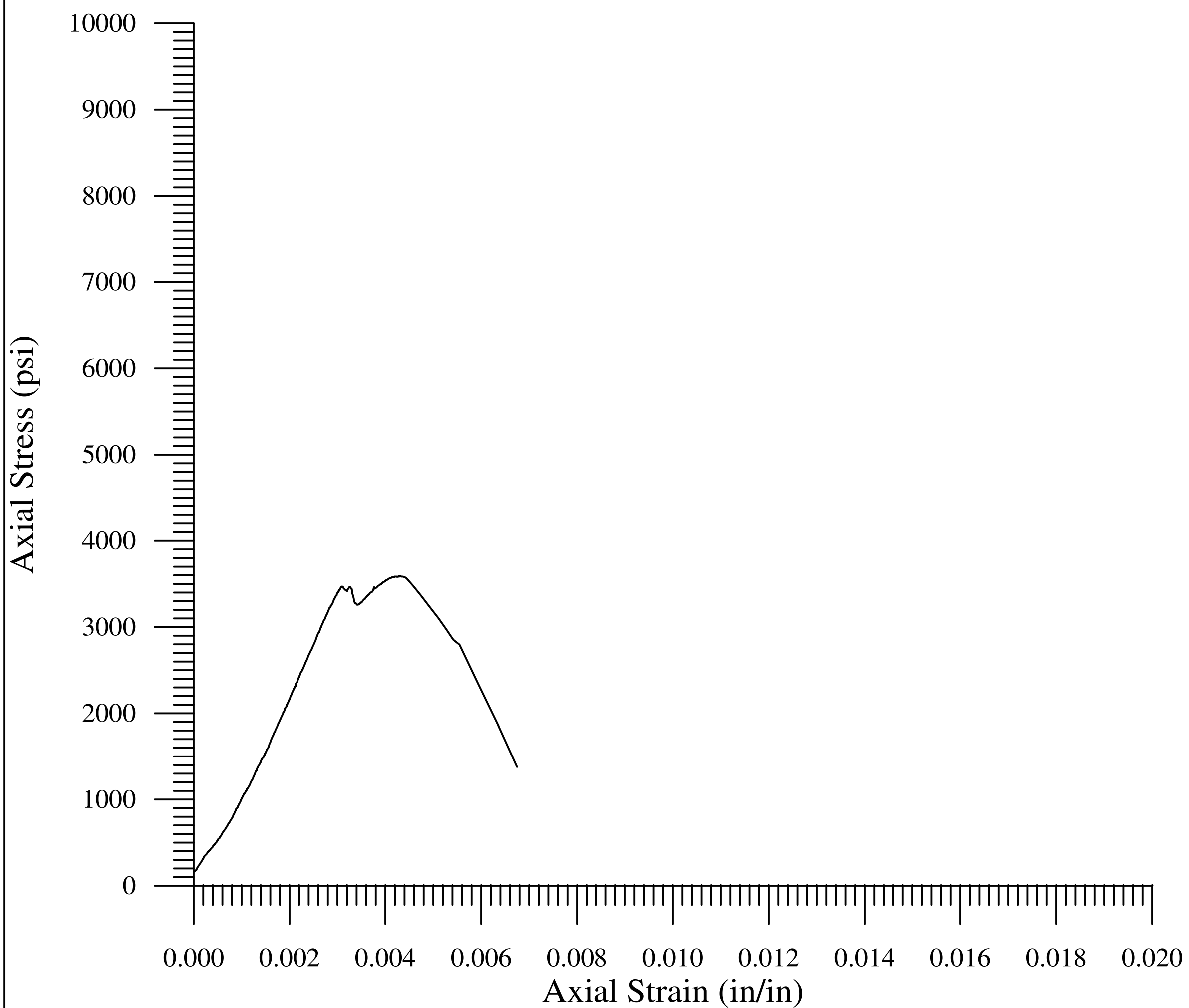
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 201
Boring: RKS-28-07
Depth: 33.0-33.8'

DESCRIPTION

Medium brown meta welded lapilli tuff, with a tight axial non-through-going fracture.

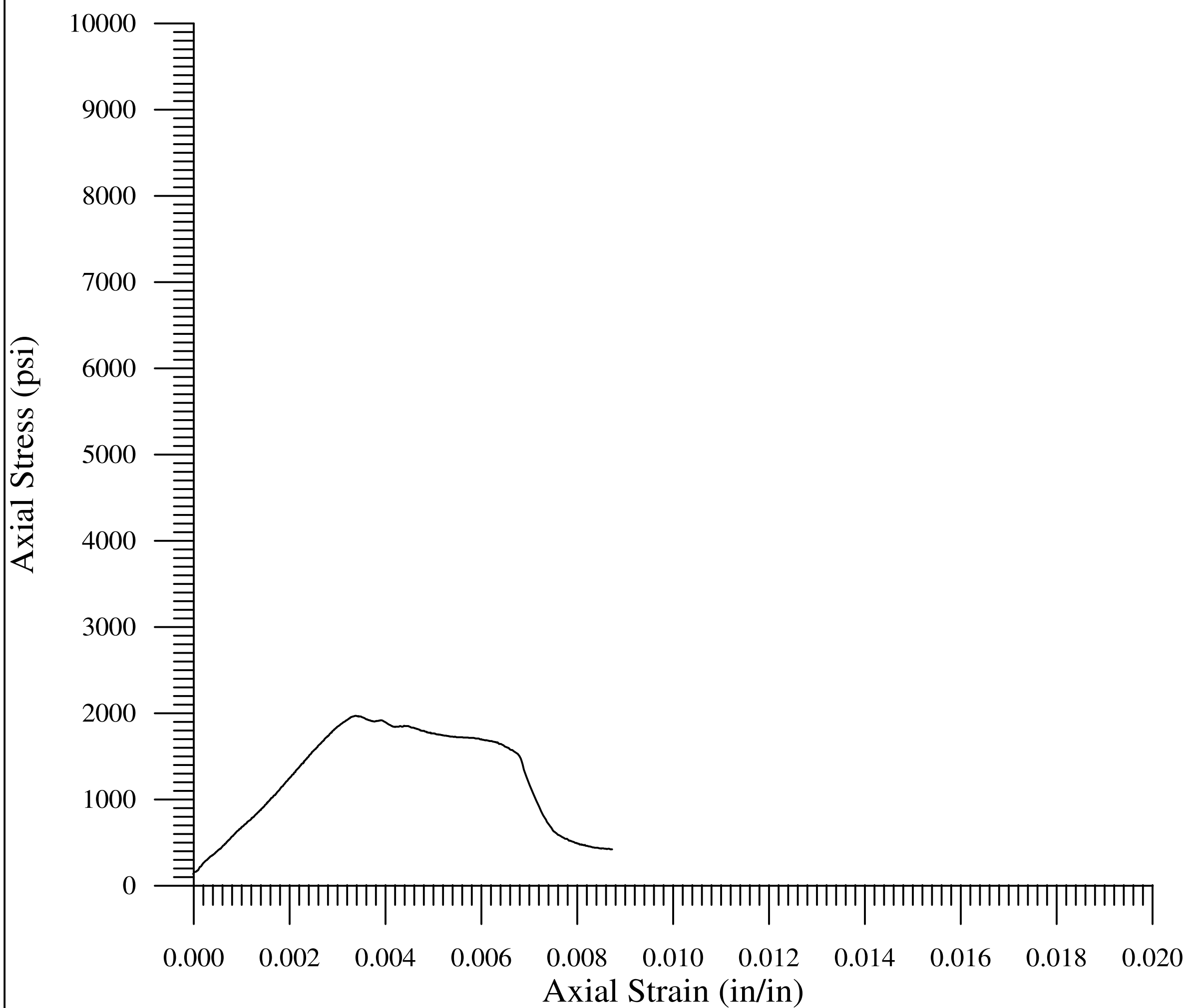
Density: 158.3 pcf
Strength: 3588 psi

Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment
Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 202
Boring: RKS-28-07
Depth: 27.8-28.5'

DESCRIPTION

Medium brown meta welded lapilli tuff,
with two major axial fractures.

Density: 156.2 pcf
Strength: 1970 psi

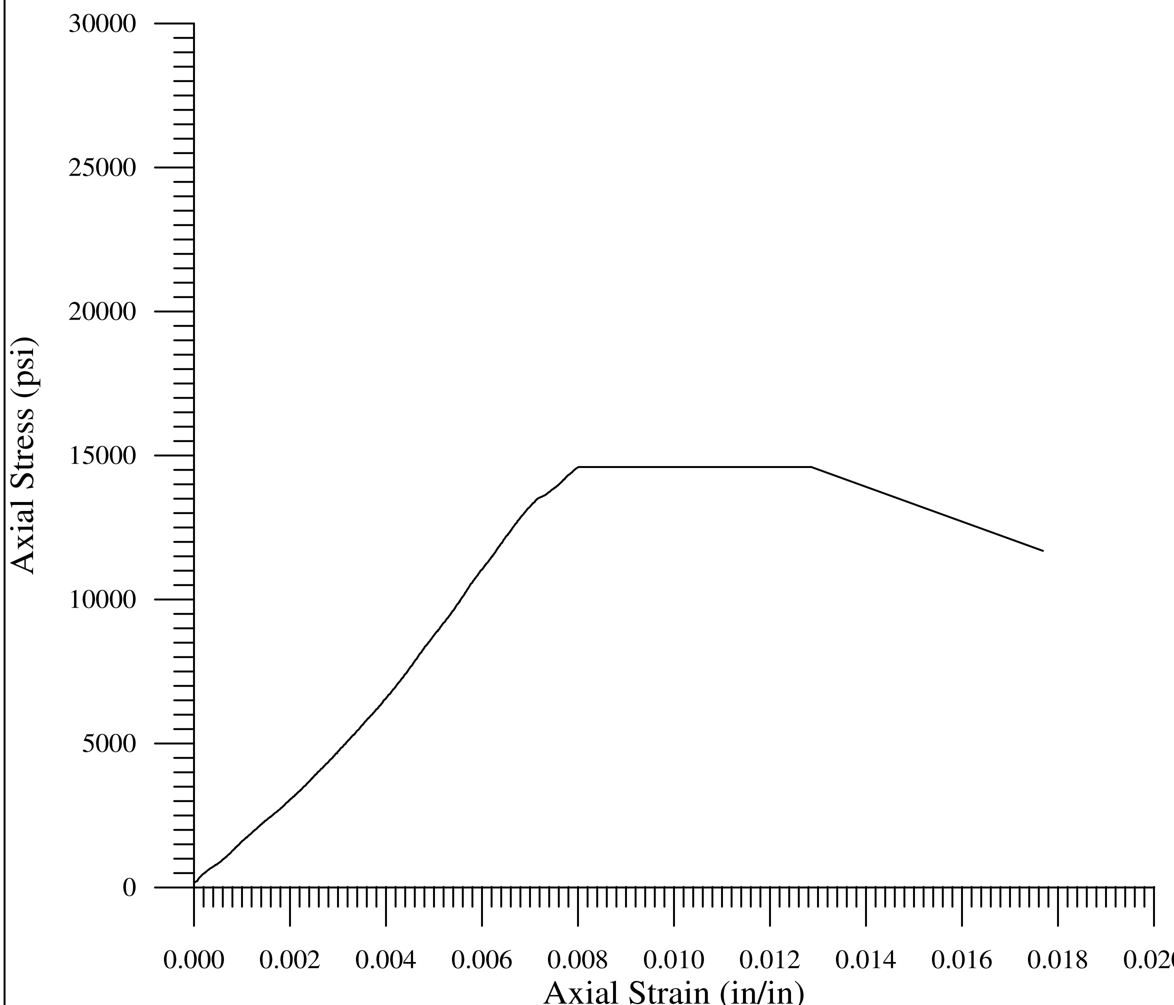
Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102A
Boring: RKS-29-07
Depth: 18.8-19.5'

DESCRIPTION

Medium gray meta welded lapilli tuff, with no apparent planes of weakness (finer clasts than other samples).

Density: 159.4 pcf
Strength: 14,605 psi

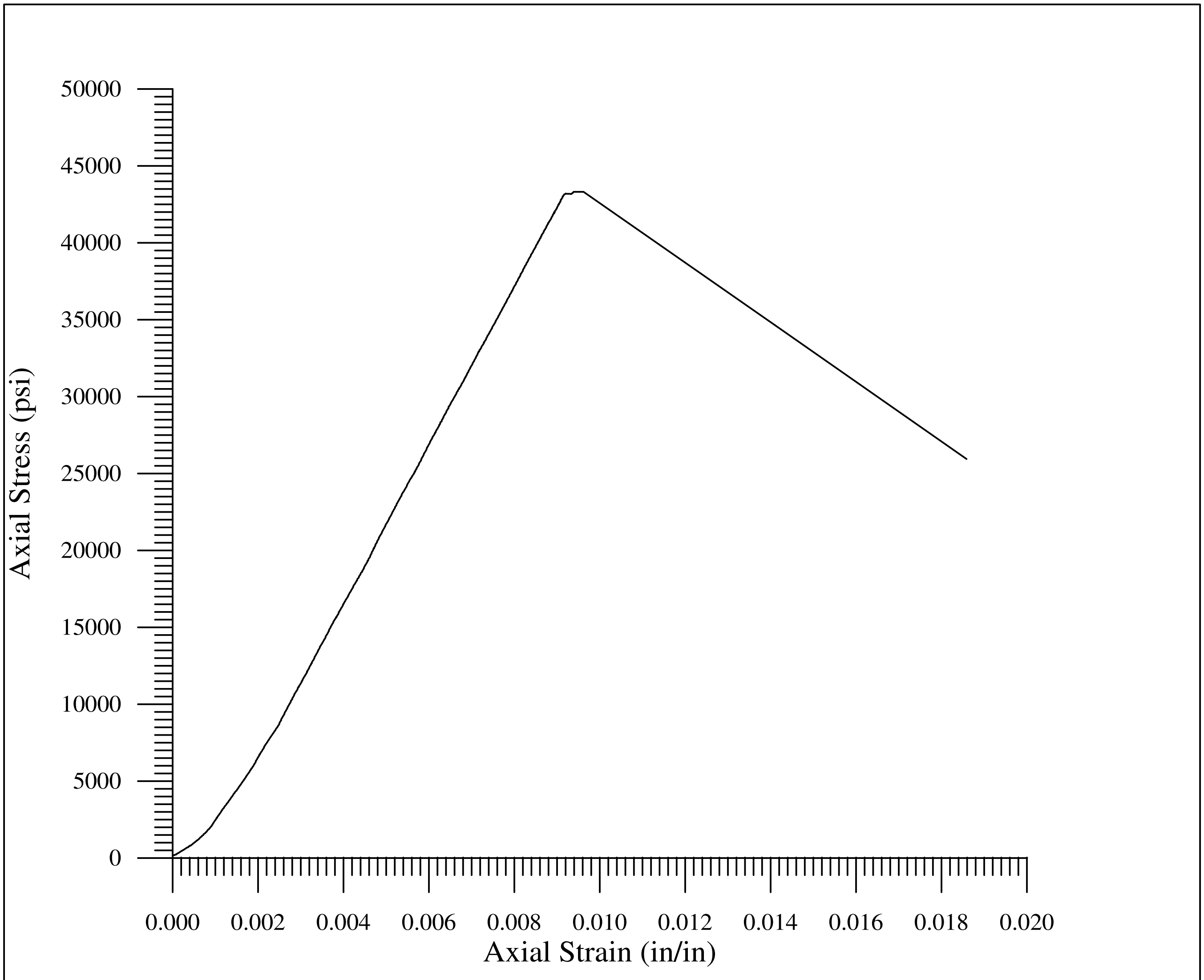
Geo Test Unlimited (GTU)
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 103A
Boring: RKS-30-07
Depth: 55.1-55.8'

DESCRIPTION

Medium blue gray meta welded lapilli tuff, with no apparent planes of weakness.

Density: 161.7 pcf
Strength: 43,320 psi

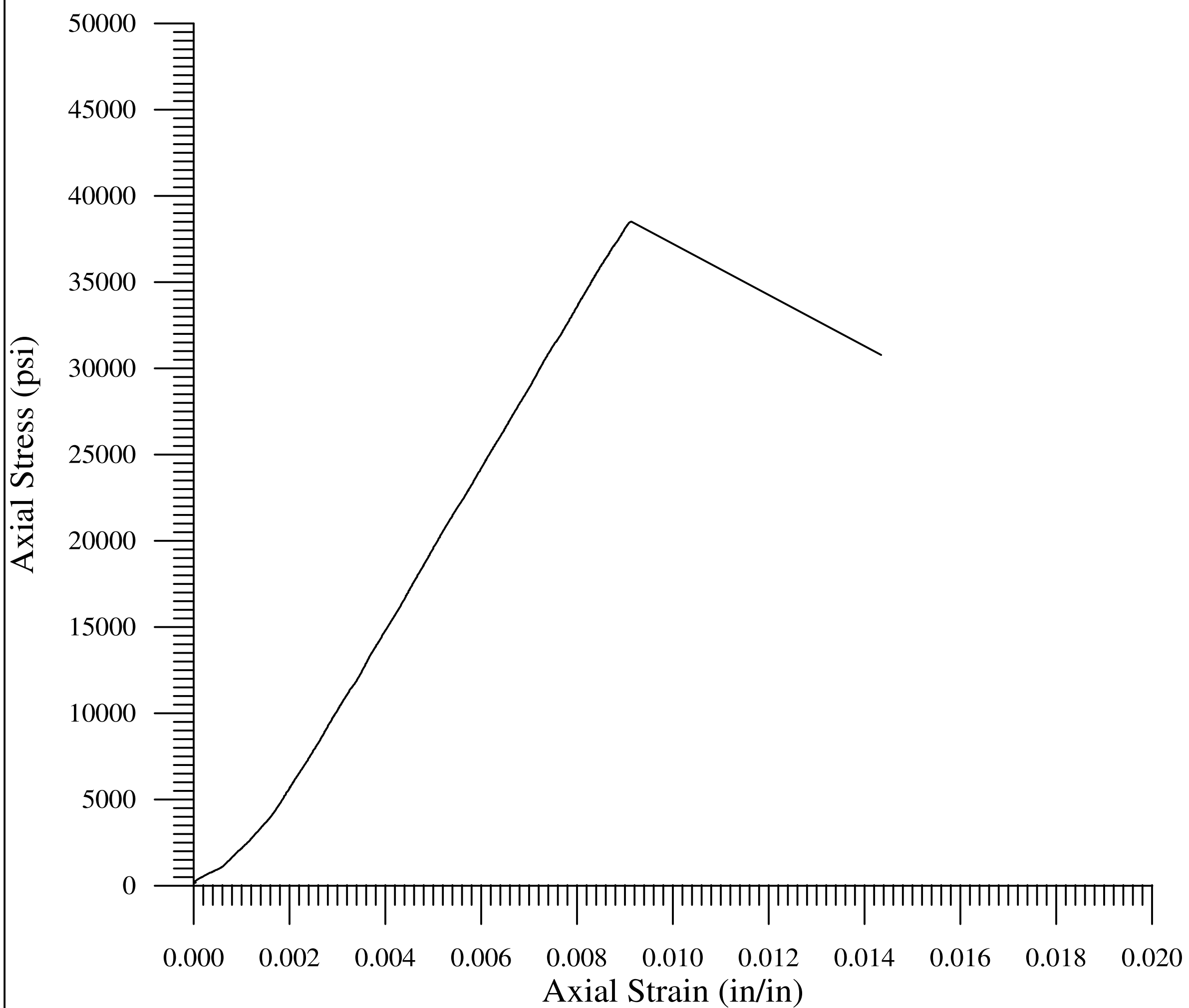
Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 103B
Boring: RKS-31-07
Depth: 83.5-84.3'

DESCRIPTION

Medium gray meta welded lapilli tuff, with no apparent planes of weakness.

Density: 162.4 pcf
Strength: 38,505 psi

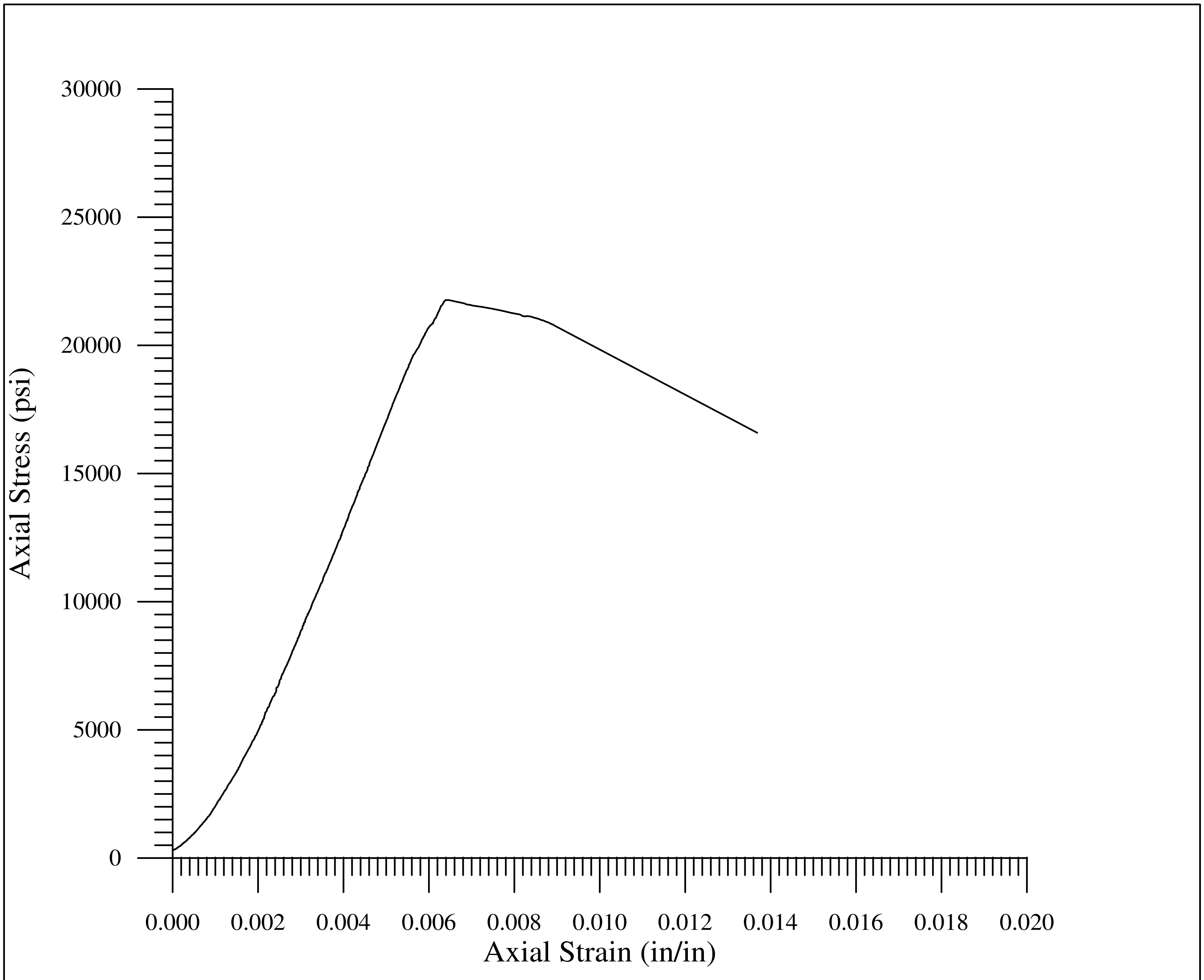
Geo Test Unlimited (GTU)
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 16, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101A
Boring: SI-10-07
Depth: 24.7-25.4'

DESCRIPTION

Medium blue gray meta welded lapilli tuff, with no apparent planes of weakness.

Density: 163.5 pcf
Strength: 21,770 psi

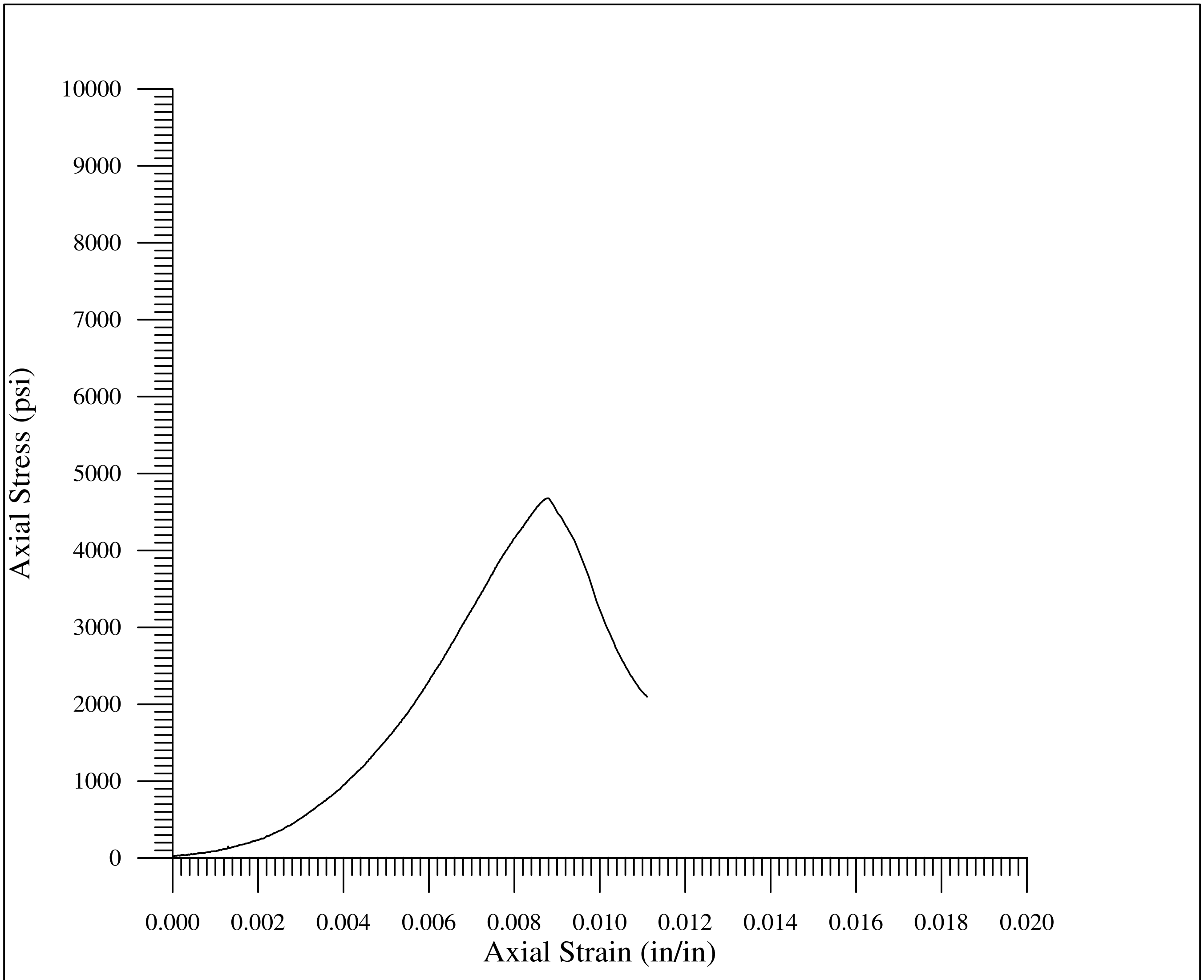
Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101
Boring: SI-1-07
Depth: 32.0-32.7'

DESCRIPTION

Medium brown meta welded lapilli tuff, altered and friable with an open oxide coated fracture.

Density: 155.1 pcf
Strength: 4680 psi

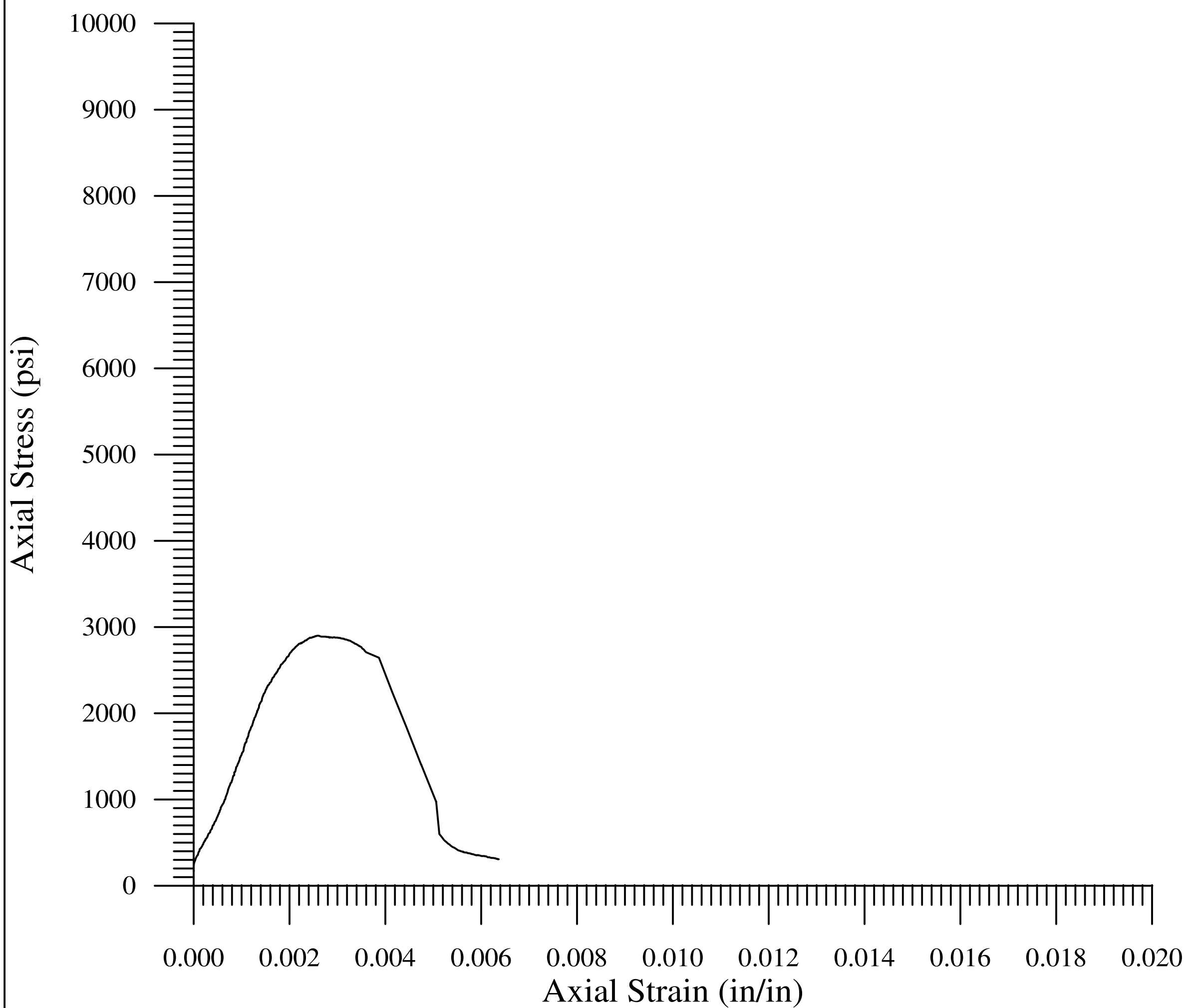
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 103A
Boring: SI-2-07
Depth: 53.4-54.0'

DESCRIPTION

Medium brown meta welded lapilli tuff, altered with several oxide healed joints.

Density: 160.5 pcf
Strength: 2901 psi

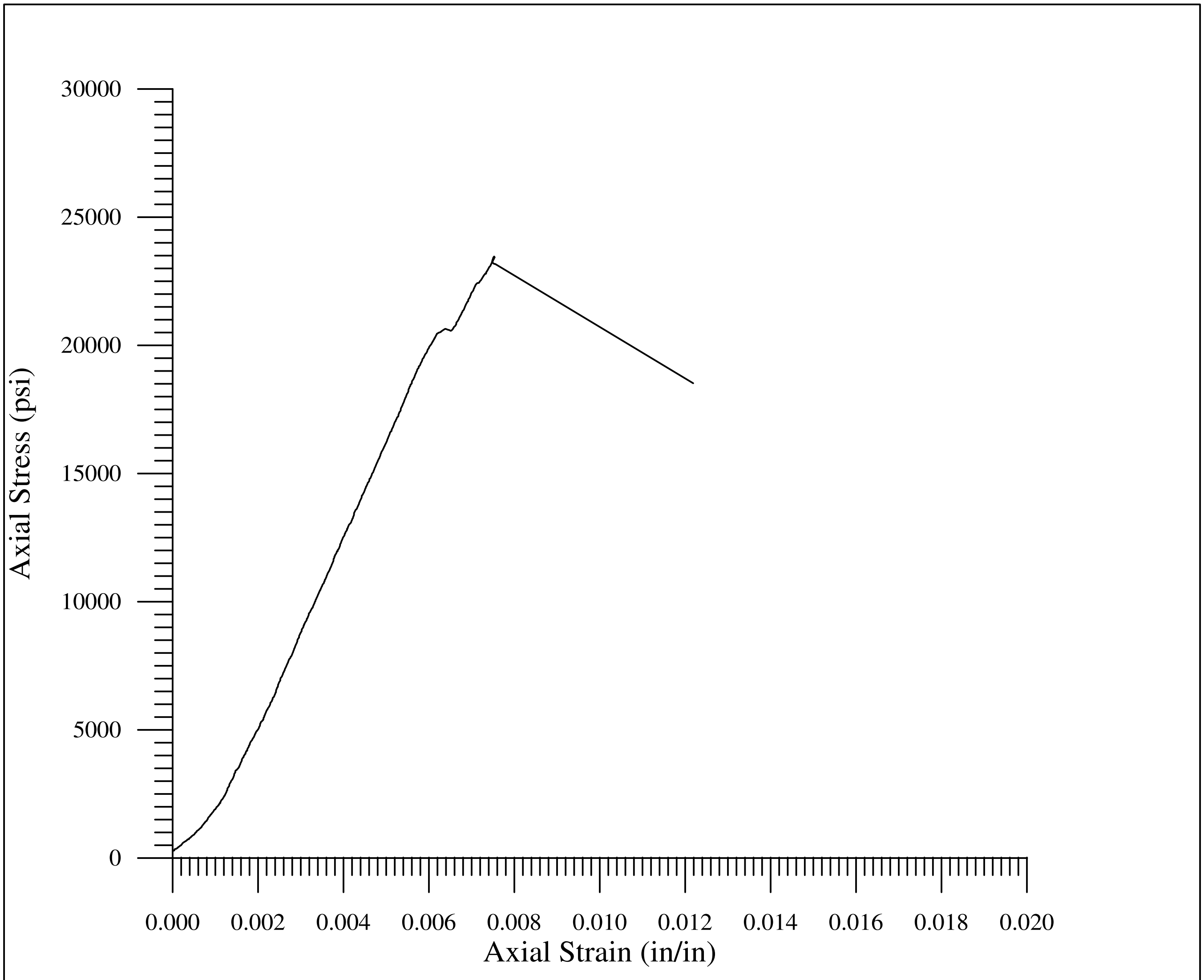
Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101A
Boring: SI-4-07
Depth: 23.6-24.5'

DESCRIPTION

Medium blue gray meta welded lapilli tuff, with a glued fracture at one end.

Density: 162.9 pcf
Strength: 23,469 psi

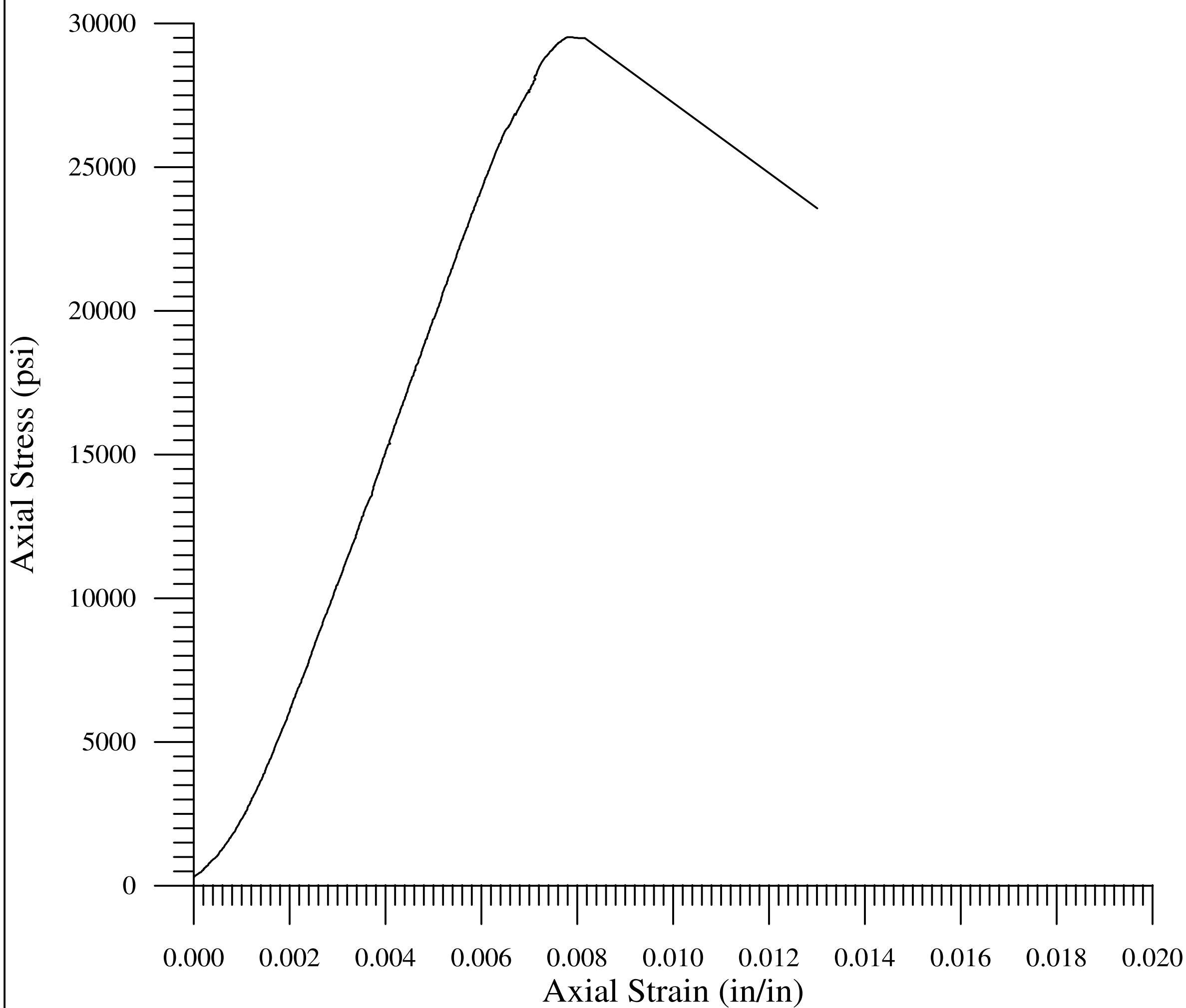
Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102A
Boring: SI-5-07
Depth: 33.9-34.8'

DESCRIPTION

Light greenish gray meta welded lapilli tuff, with no apparent planes of weakness.

Density: 165.0 pcf
Strength: 29,523 psi

Geo Test Unlimited GTU

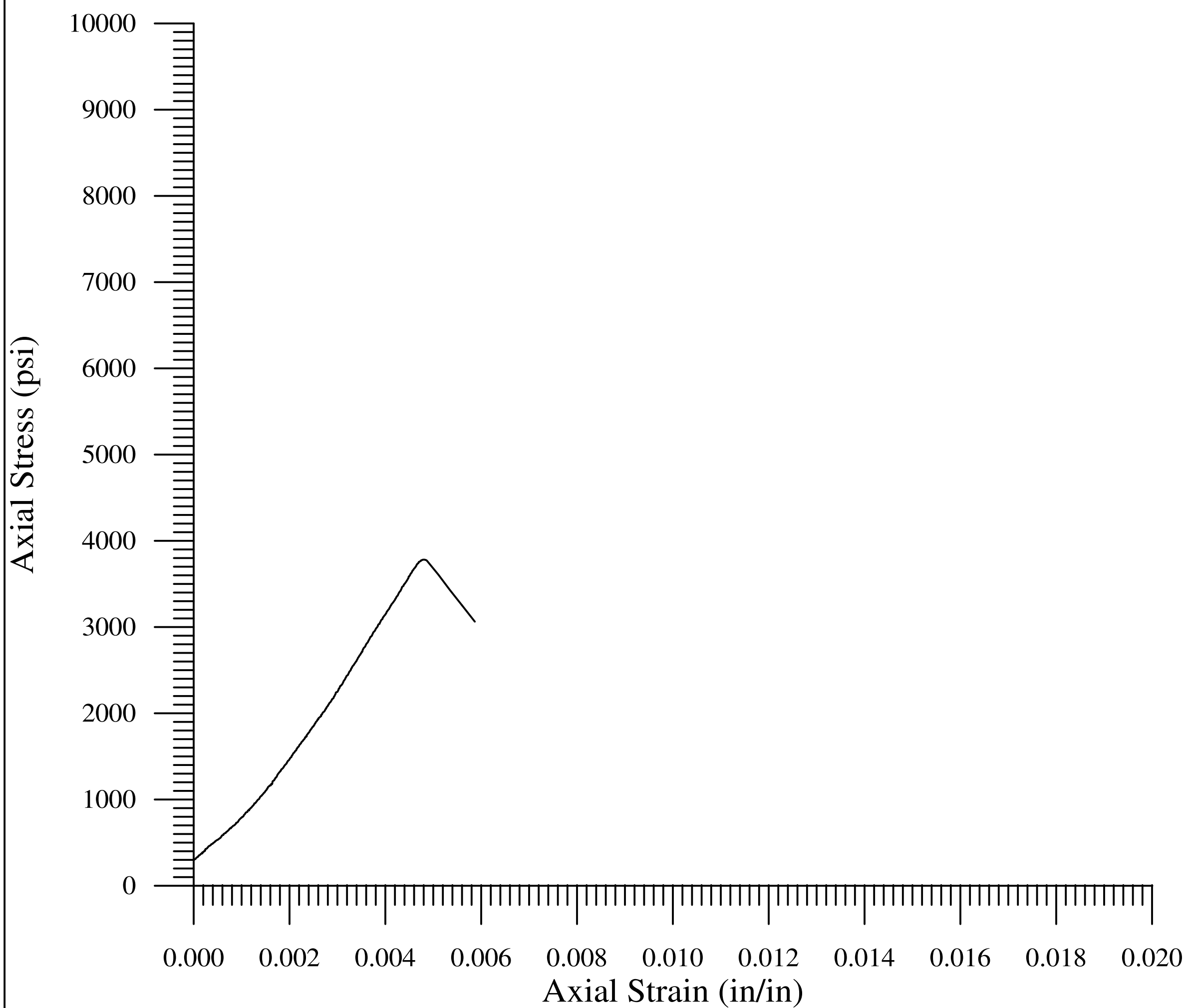
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 103
Boring: SI-5-07
Depth: 56.9-57.6'

DESCRIPTION

Medium brown meta welded lapilli tuff, slightly altered with two minor oxide stained non-through-going joints.

Density: 158.6 pcf
Strength: 3782 psi

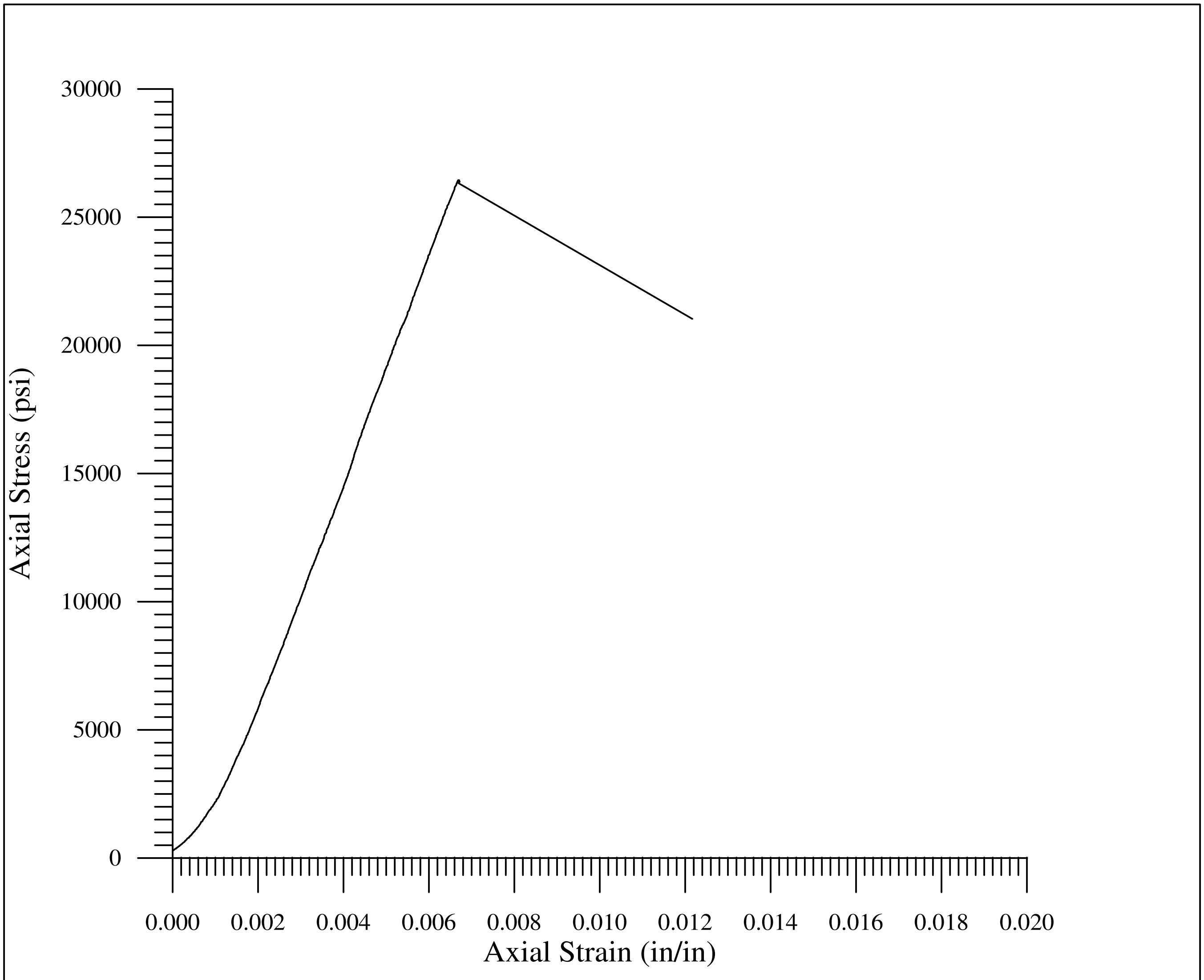
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101B
Boring: SI-7-07
Depth: 36.9-37.4'

DESCRIPTION

Medium gray meta welded lapilli tuff, with slight oxide staining, but no apparent planes of weakness.

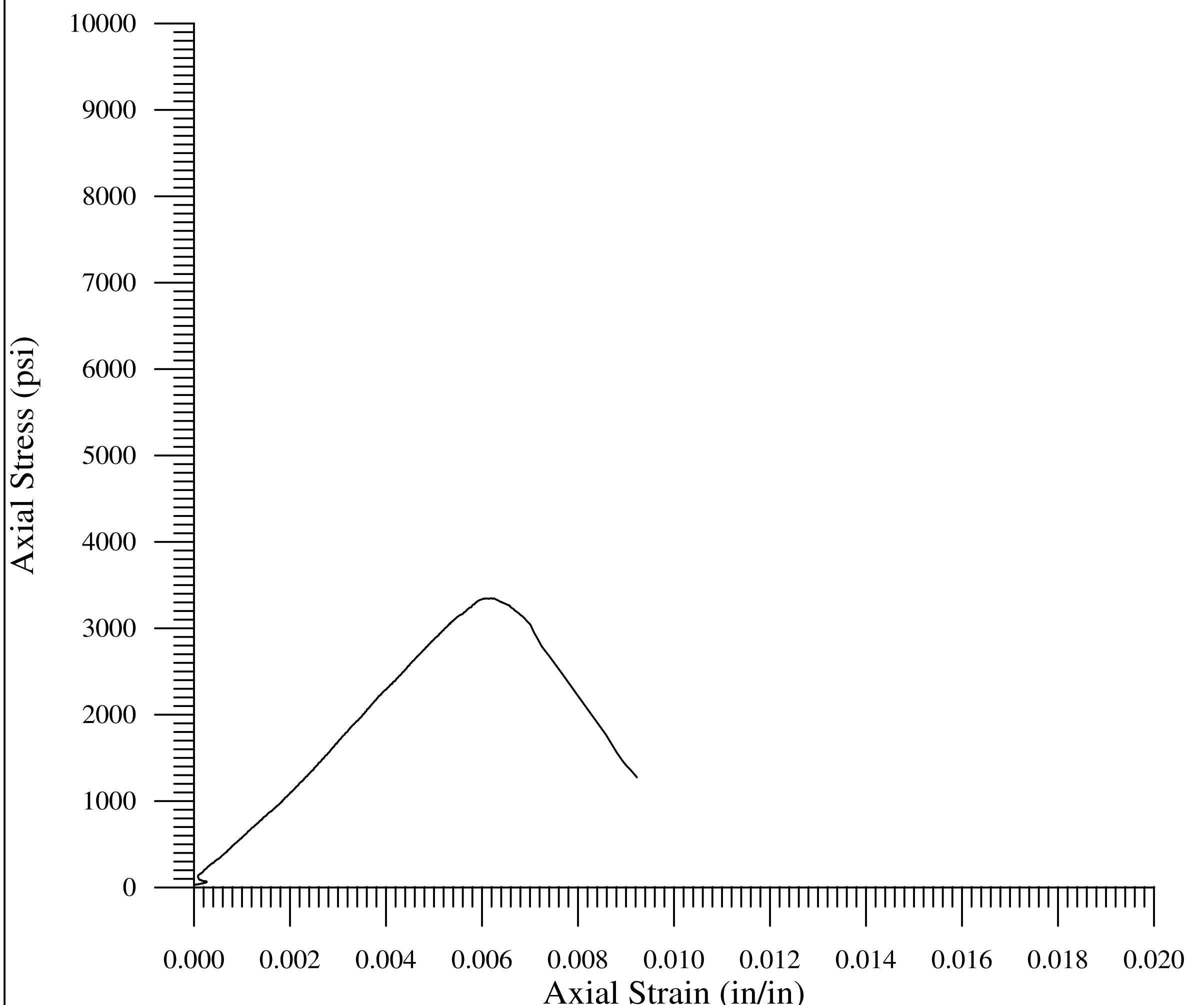
Density: 163.5 pcf
Strength: 26,444 psi

Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: East I-90 Hyak Realignment
Project Number: none

Test Date: January 14, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 201
Boring: SI-9-07
Depth: 42.4-43.1'

DESCRIPTION

Medium brown meta welded lapilli tuff, somewhat friable with several oxide stained joints.

Density: 158.9 pcf
Strength: 3348 psi

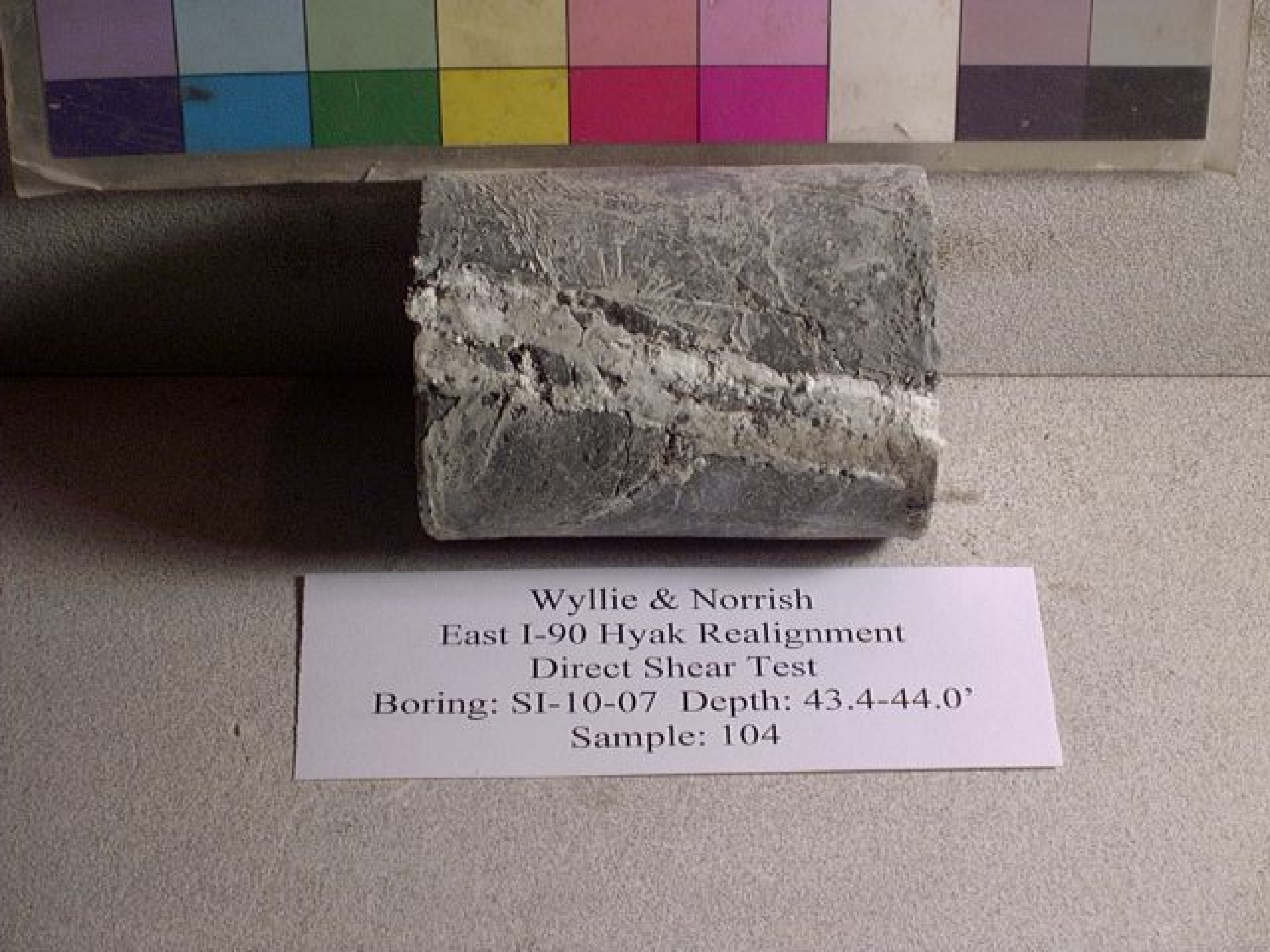
Geo Test Unlimited GTU
27069 N. Bloomfield Rd.
Nevada City, CA 95959

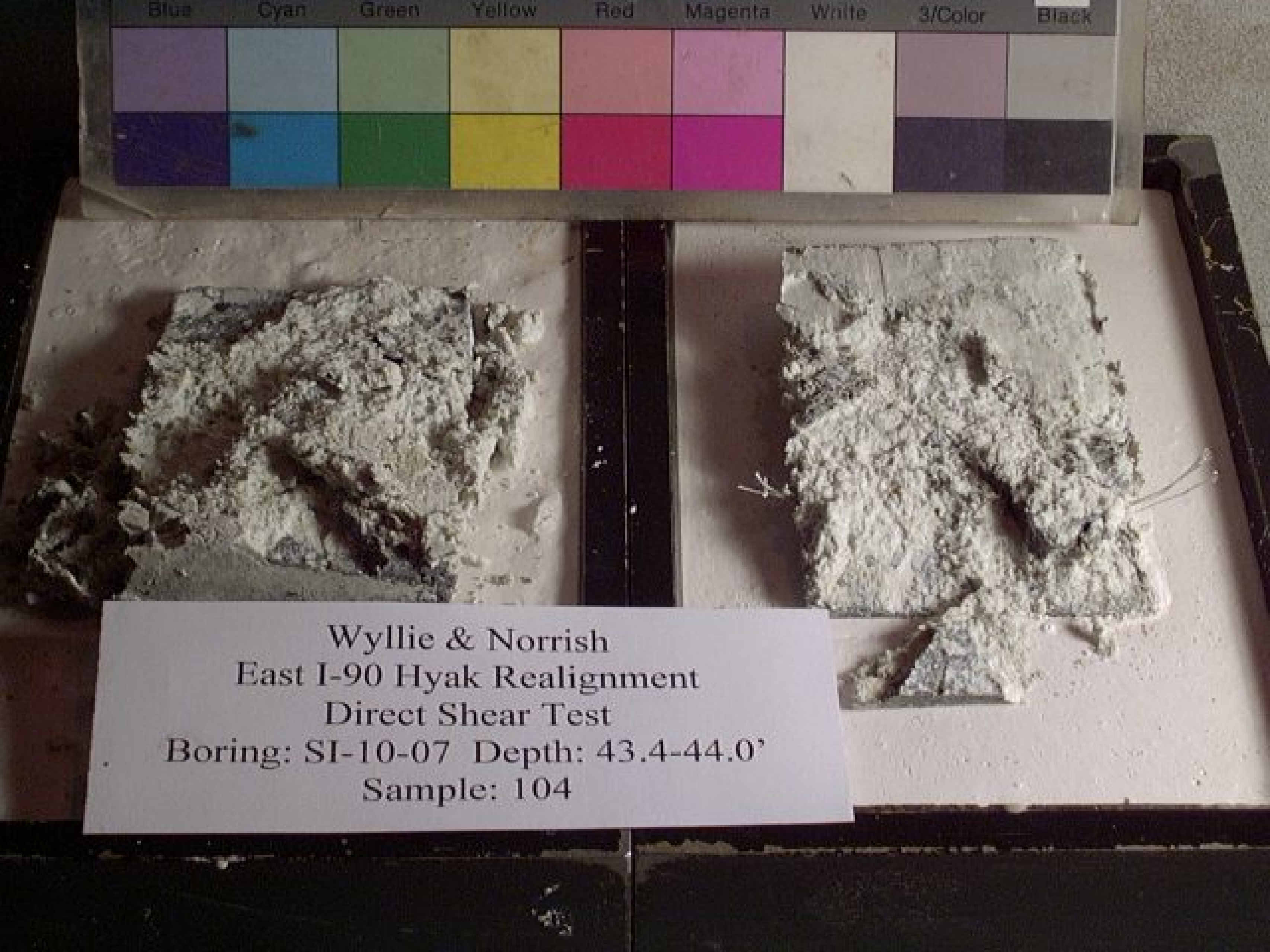
Client: Wyllie & Norrish Engineers
17918 NE 27th St.
Redmond, WA 98052

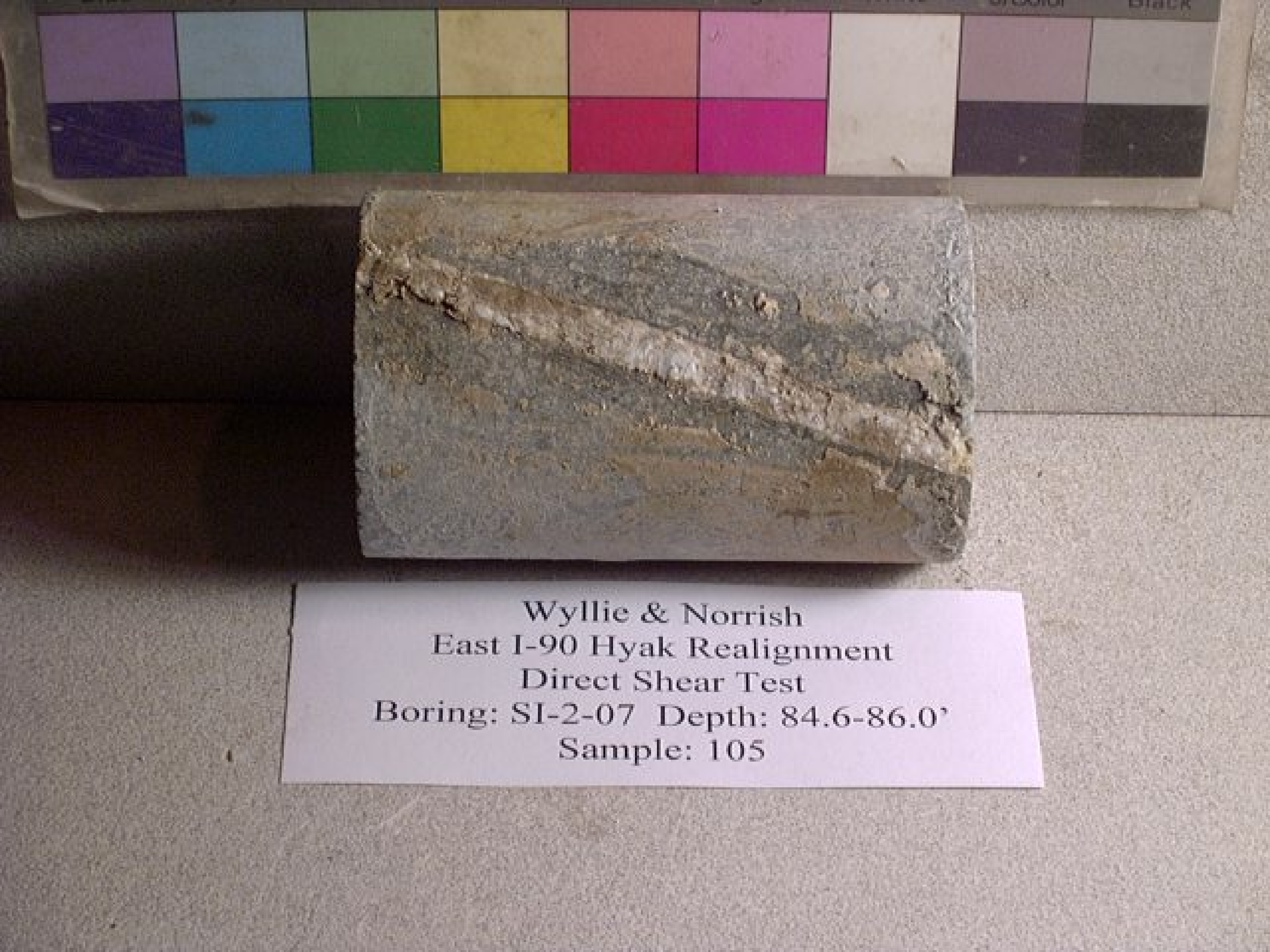
Project: East I-90 Hyak Realignment

Project Number: none

Test Date: January 14, 2008


Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: SI-10-07 Depth: 43.4-44.0’
Sample: 104


Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: SI-10-07 Depth: 43.4-44.0’
Sample: 104


Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: SI-2-07 Depth: 84.6-86.0'
Sample: 105


Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
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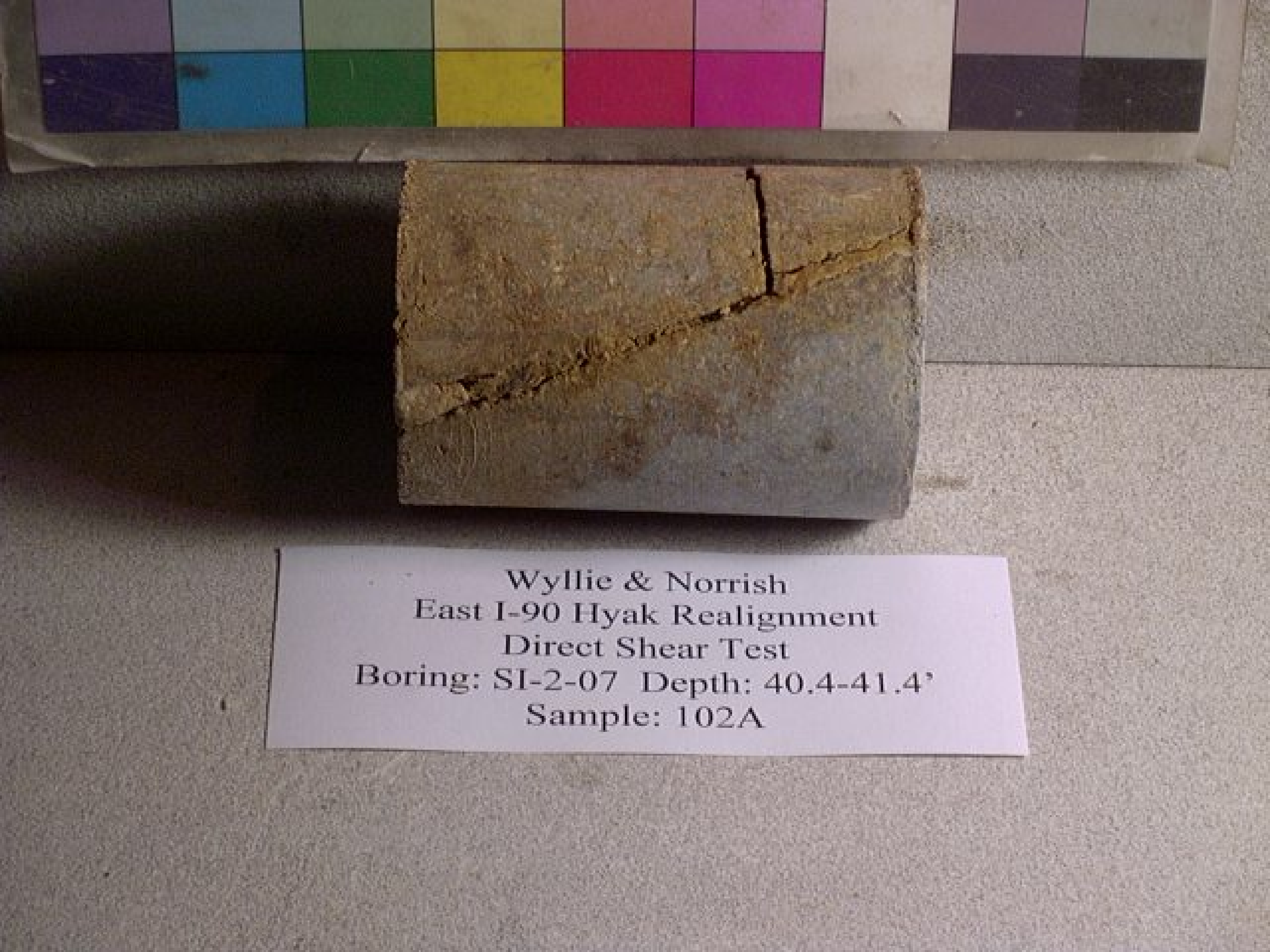
Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: SI-2-07 Depth: 84.6-86.0'
Sample: 105


Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: SI-2-07 Depth: 40.4-41.4'
Sample: 102A

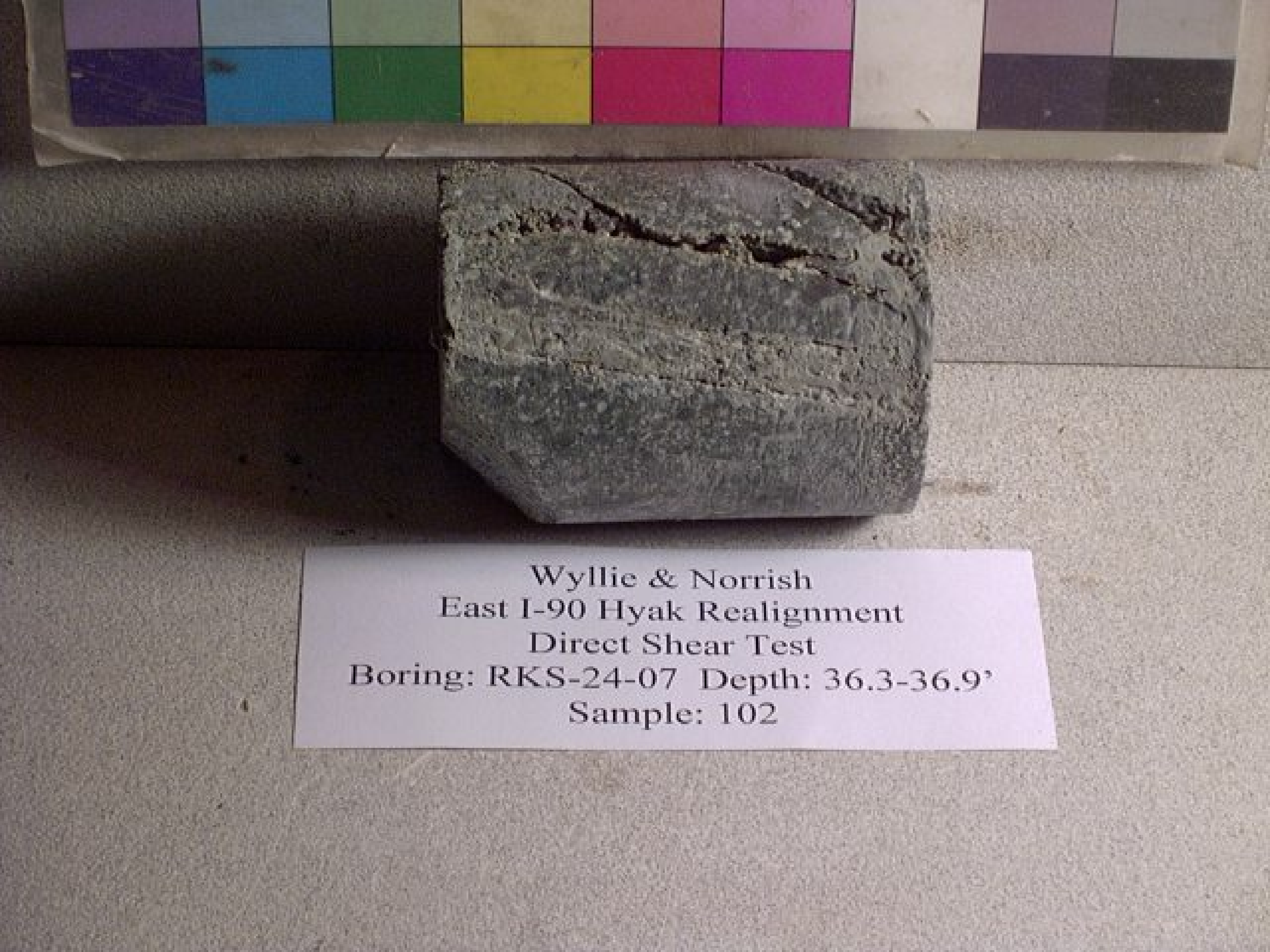

Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: SI-2-07 Depth: 40.4-41.4'
Sample: 102A


Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-30-07 Depth: 55.1-55.6'
Sample: 103A


Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-30-07 Depth: 55.1-55.6'
Sample: 103A


Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-29-07 Depth: 18.8-19.5'
Sample: 102A

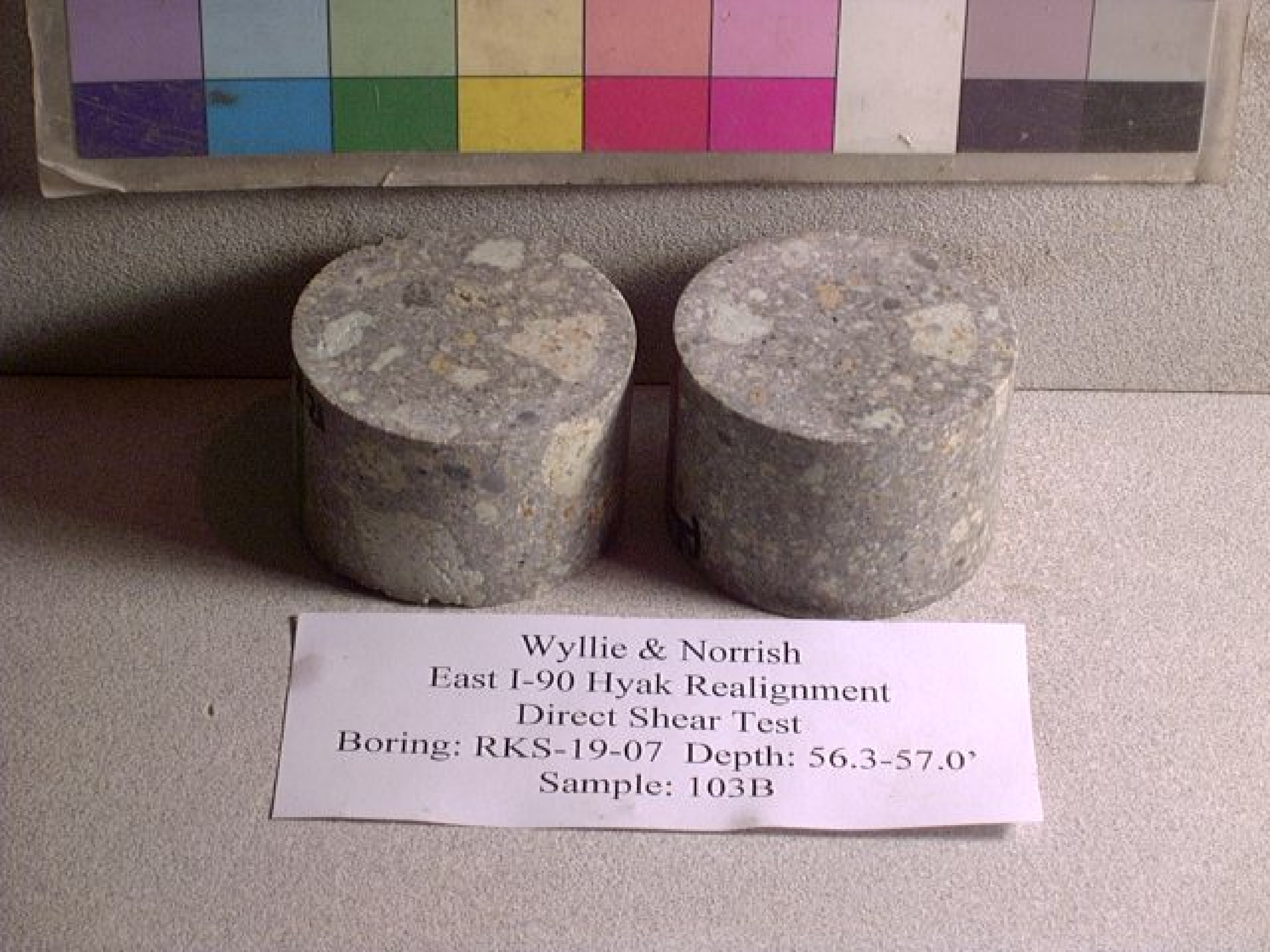

KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-29-07 Depth: 18.8-19.5'
Sample: 102A


Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-24-07 Depth: 36.3-36.9'
Sample: 102

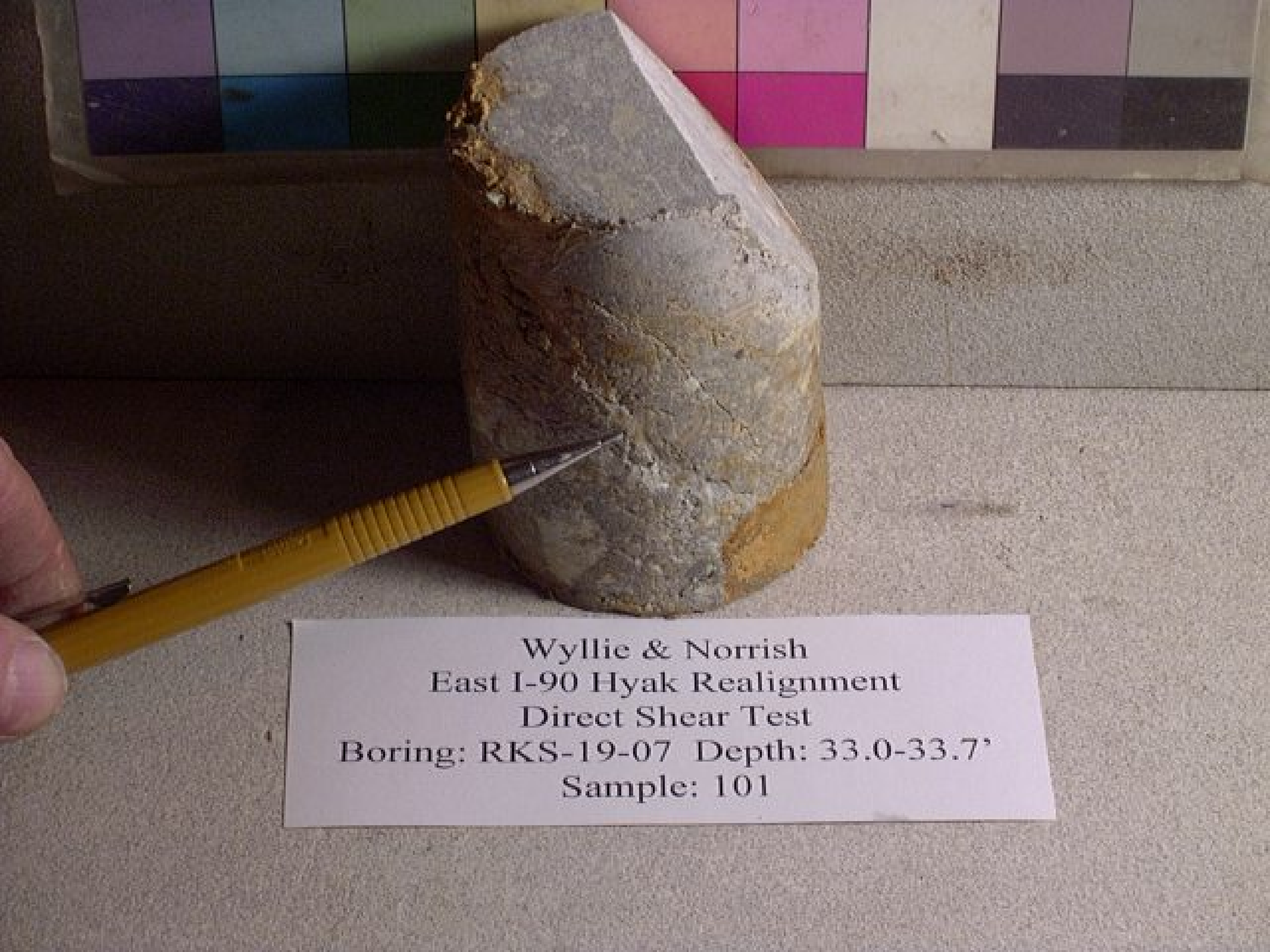

Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-24-07 Depth: 36.3-36.9'
Sample: 102


Wylie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-22-07 Depth: 11.7-12.5'
Sample: 101A

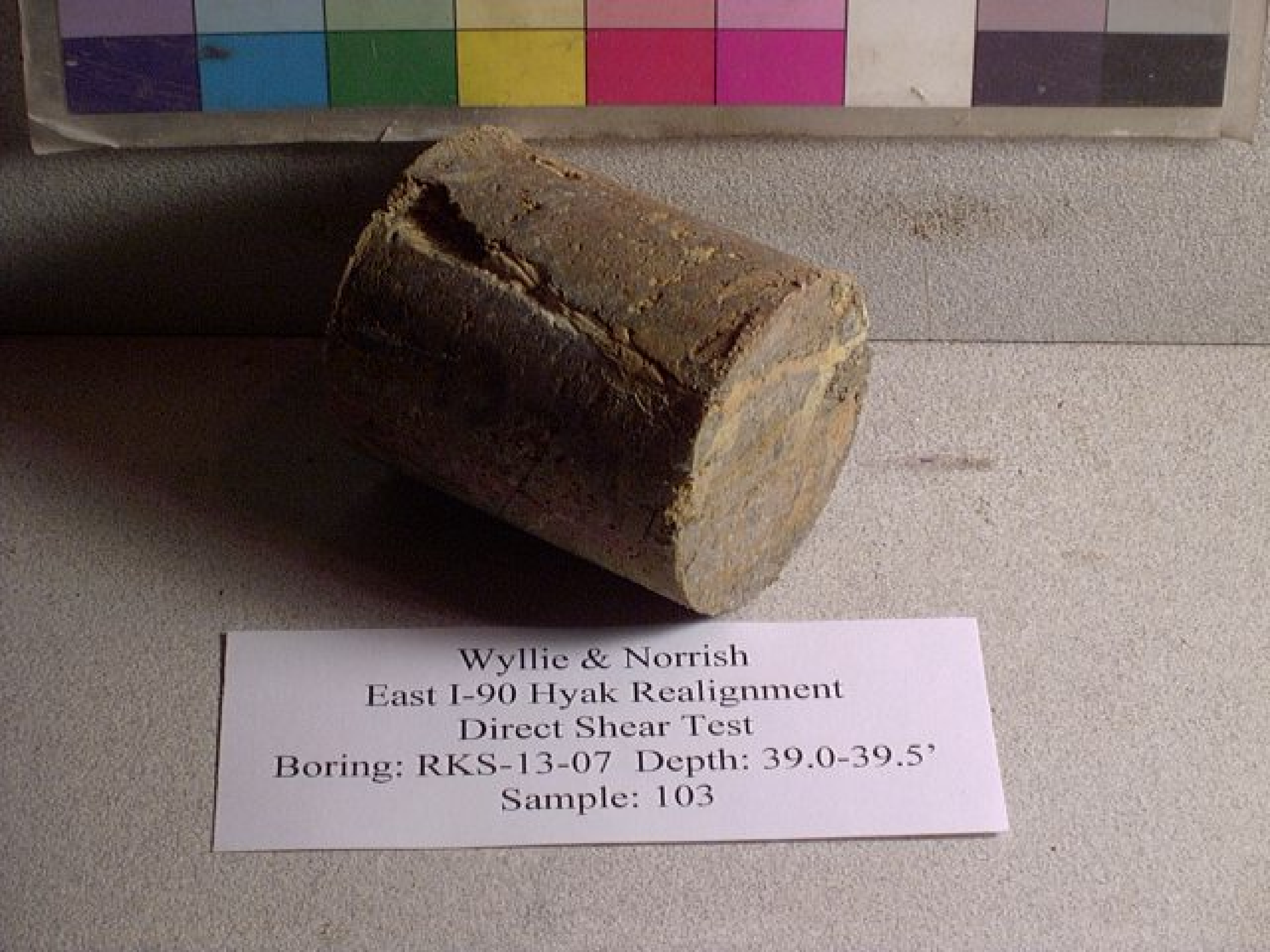

Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-22-07 Depth: 11.7-12.5'
Sample: 101A


Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-19-07 Depth: 56.3-57.0'
Sample: 103B

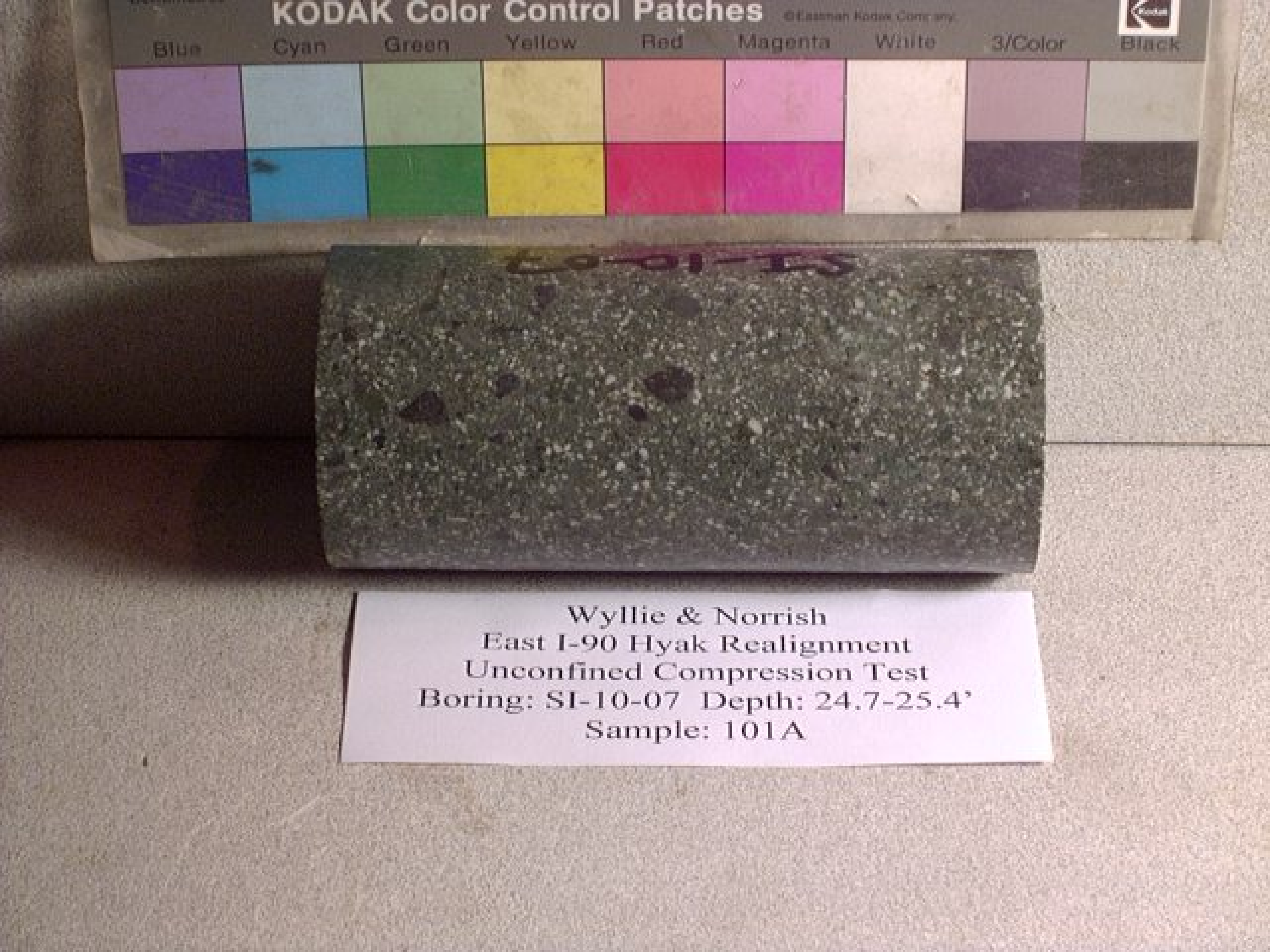

Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-19-07 Depth: 56.3-57.0'
Sample: 103B

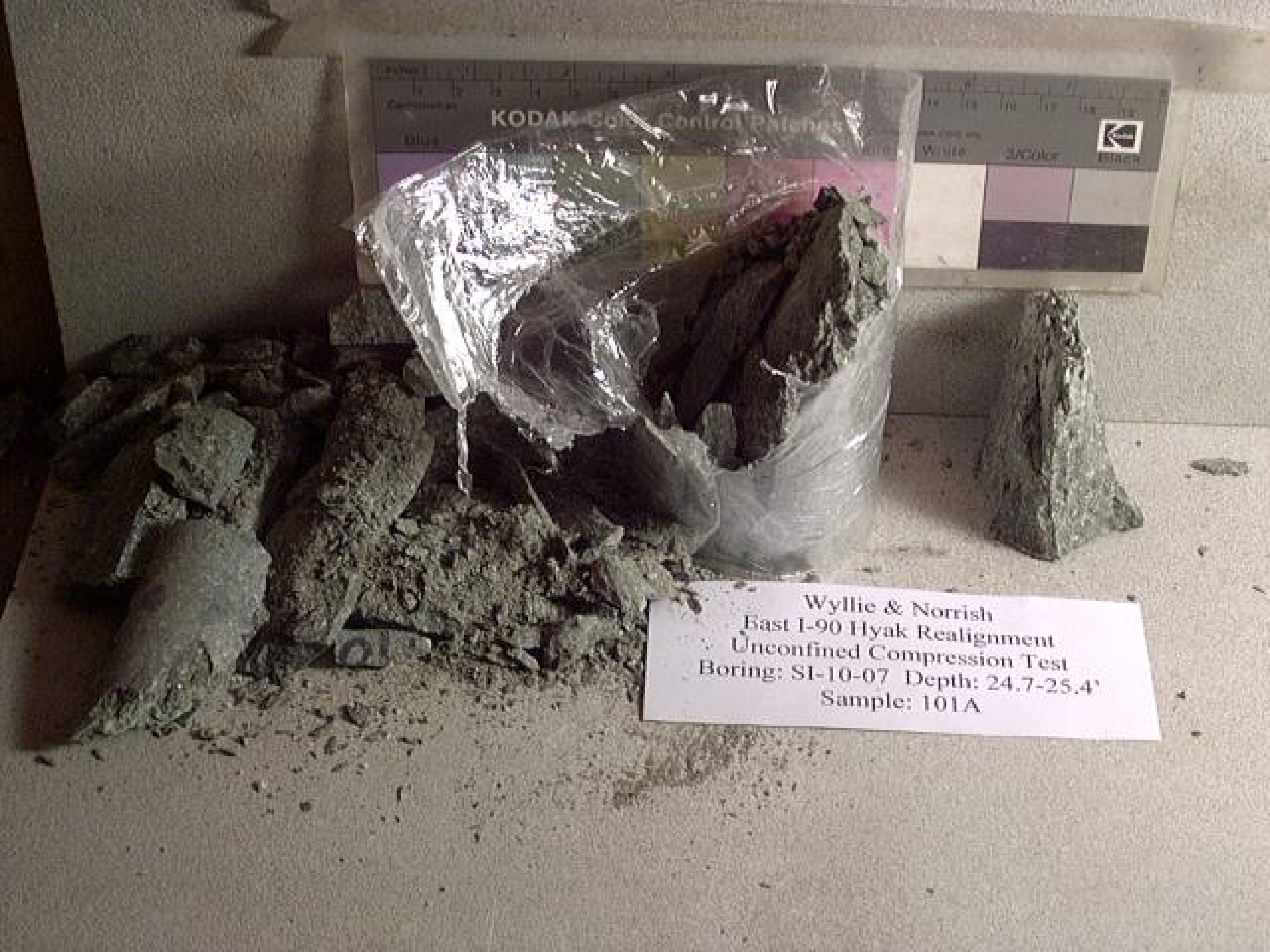

Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-19-07 Depth: 33.0-33.7'
Sample: 101

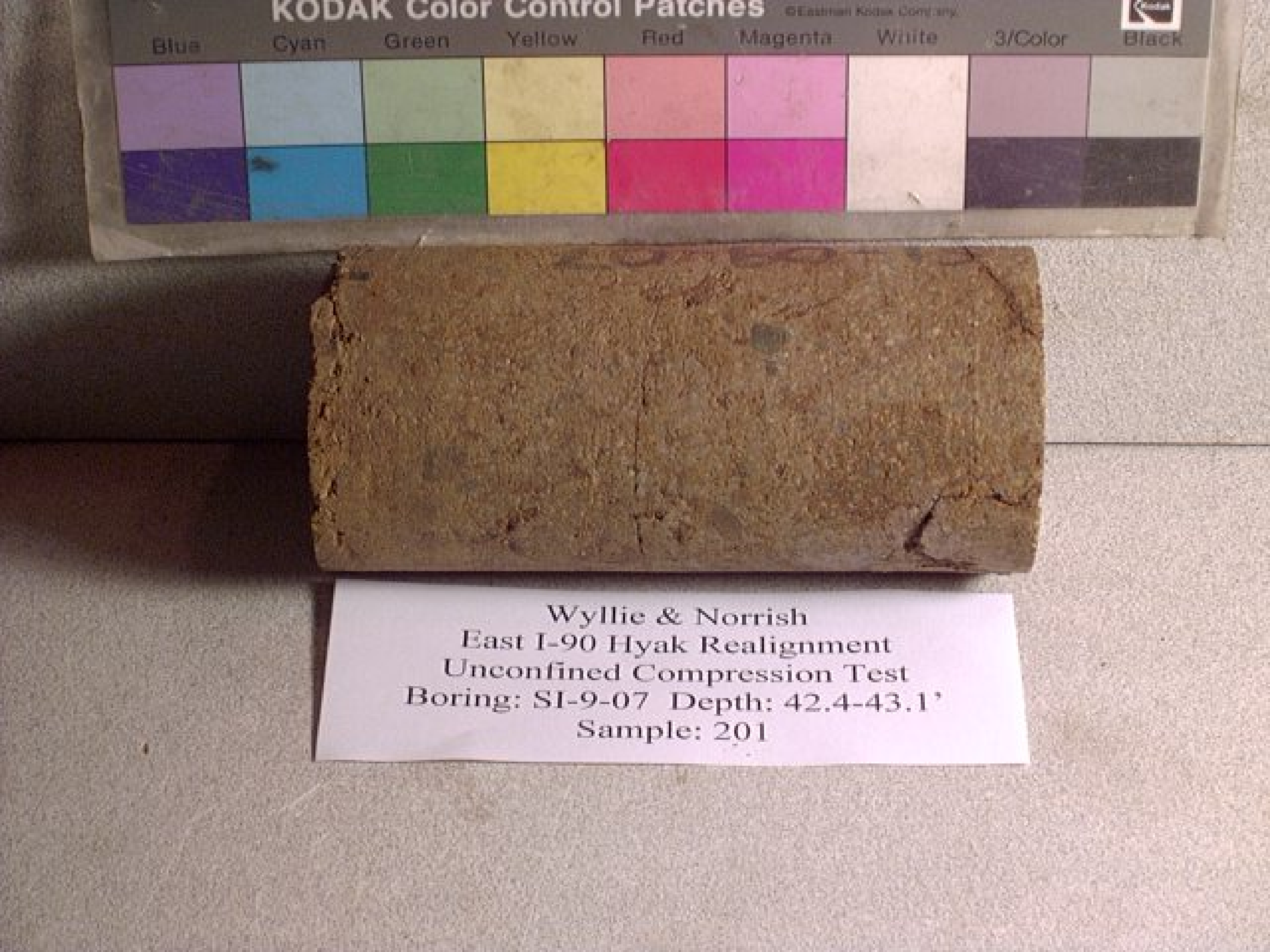

Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-19-07 Depth: 33.0-33.7’
Sample: 101

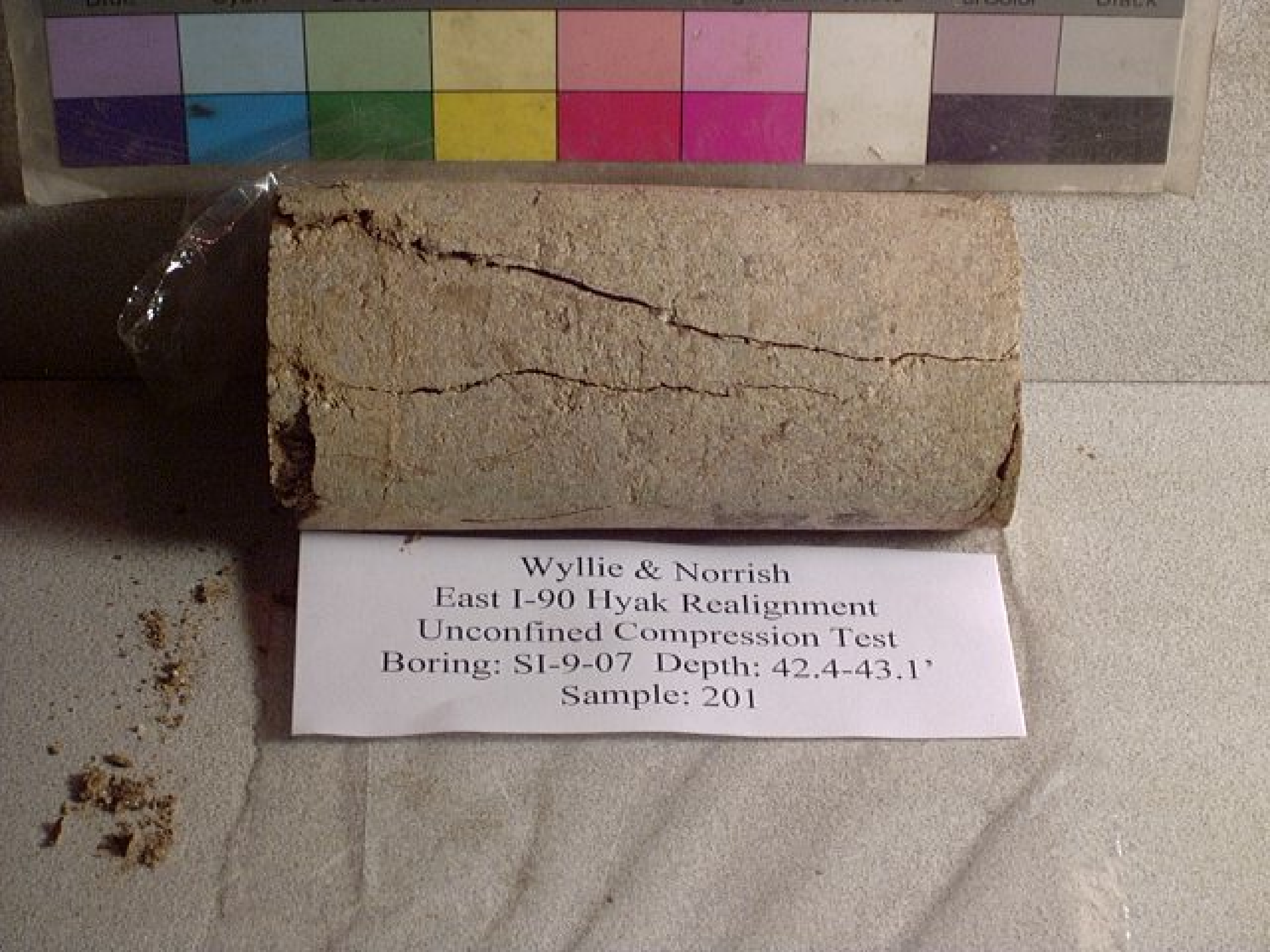

Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-13-07 Depth: 39.0-39.5'
Sample: 103

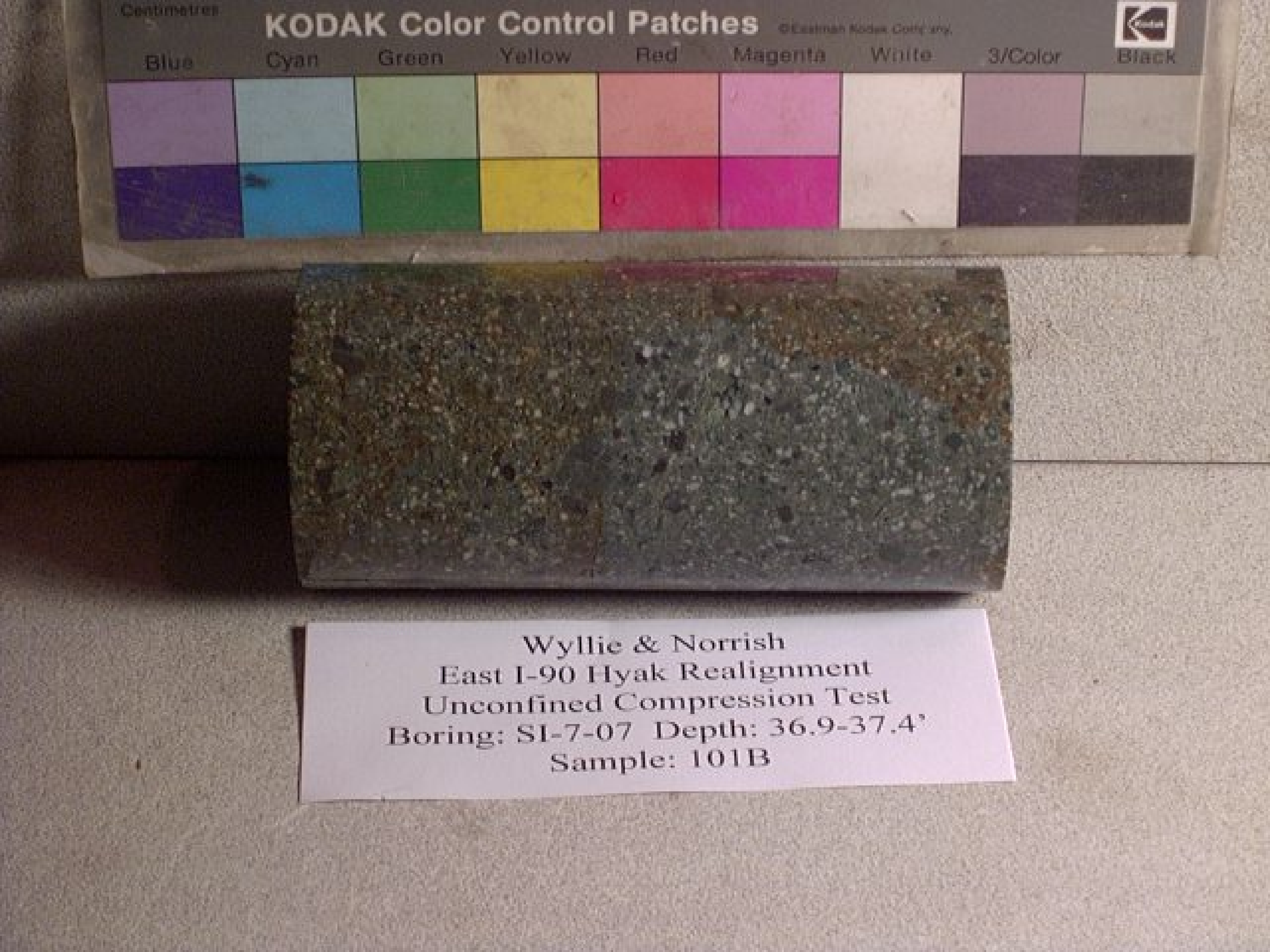

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-13-07 Depth: 39.0-39.5'
Sample: 103


KODAK Color Control Patches
©Eastman Kodak Company
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-10-07 Depth: 24.7-25.4'
Sample: 101A

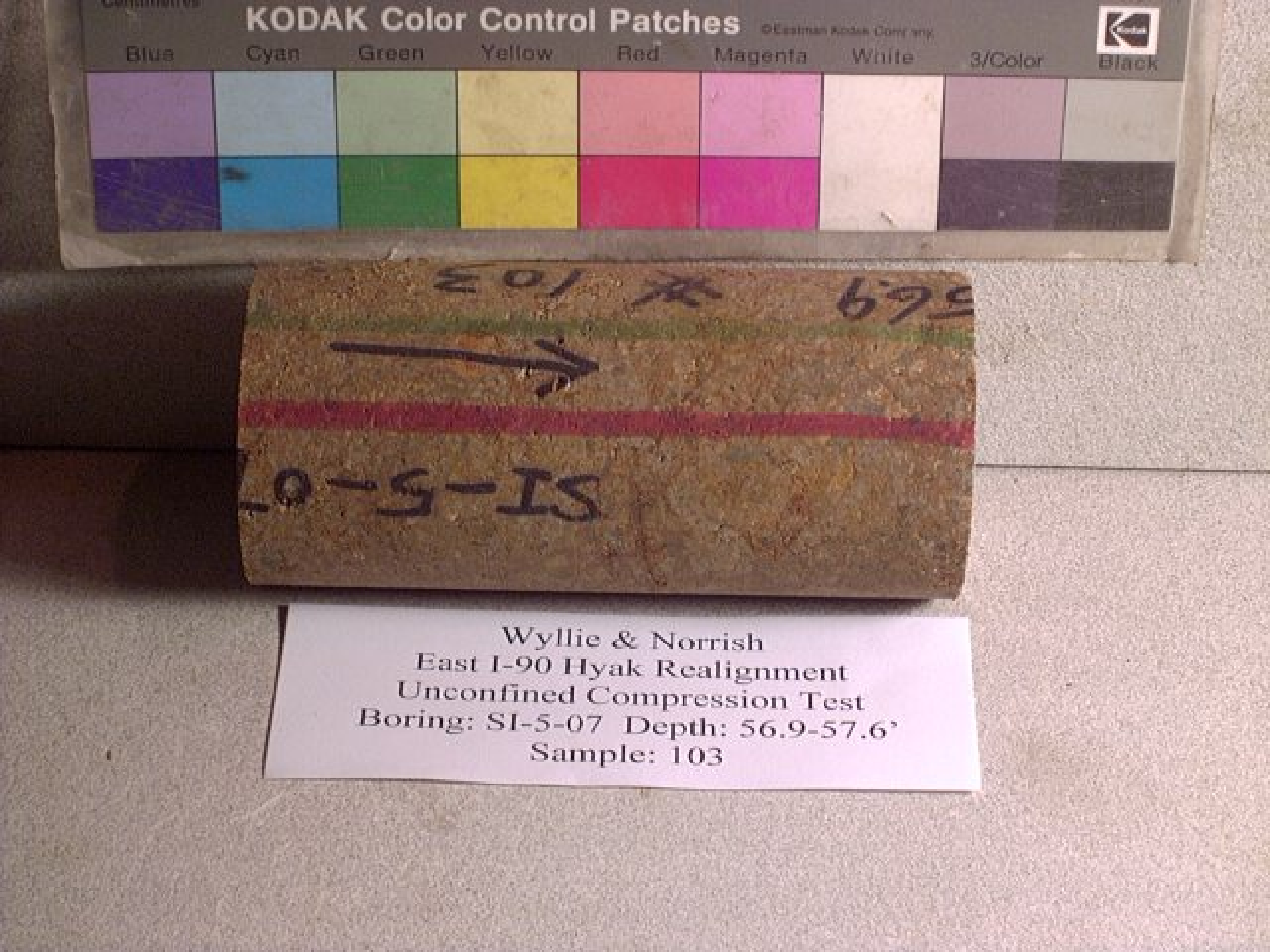

KODAK Color Control Patches
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-10-07 Depth: 24.7-25.4'
Sample: 101A

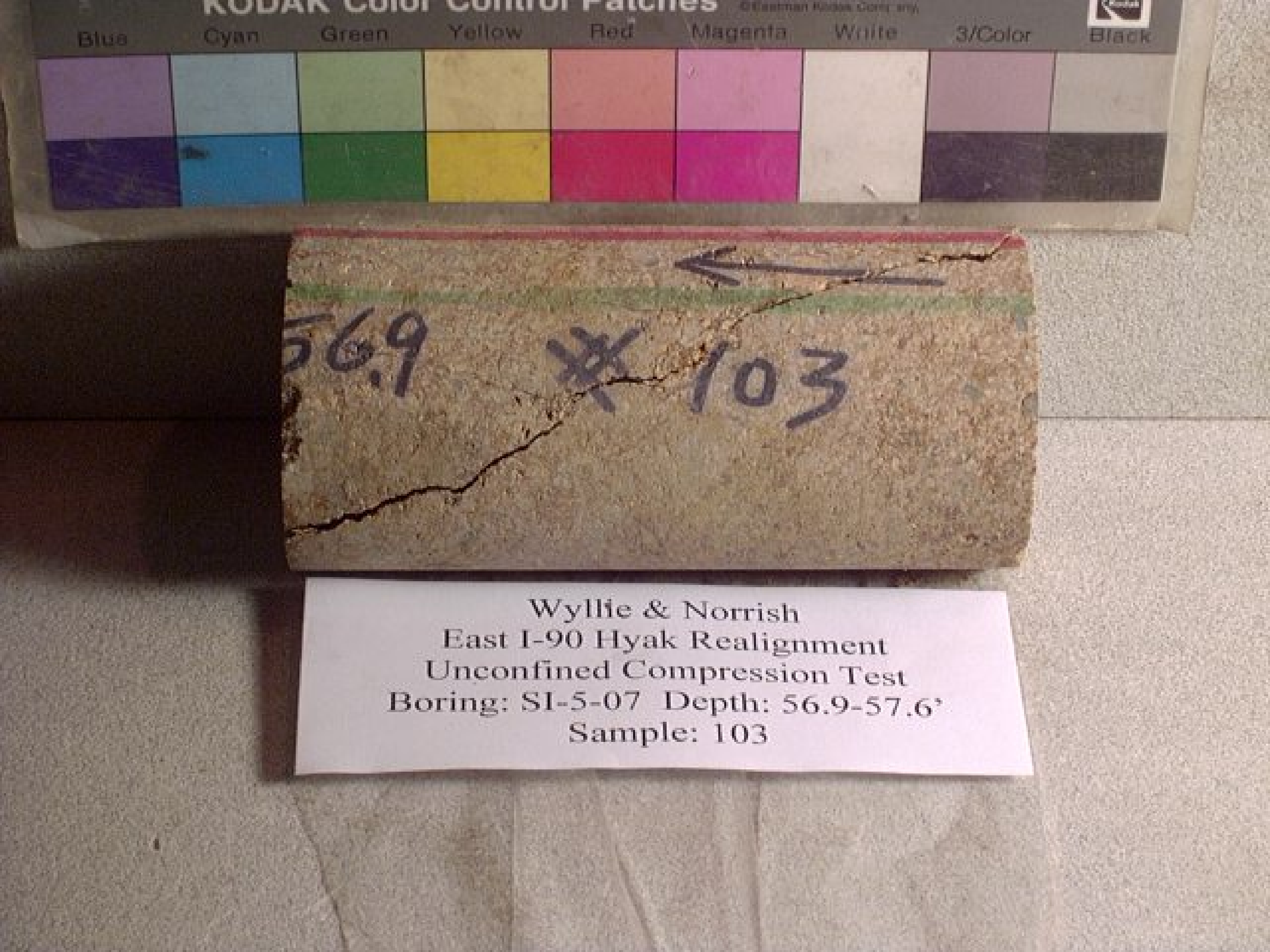

KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-9-07 Depth: 42.4-43.1'
Sample: 201

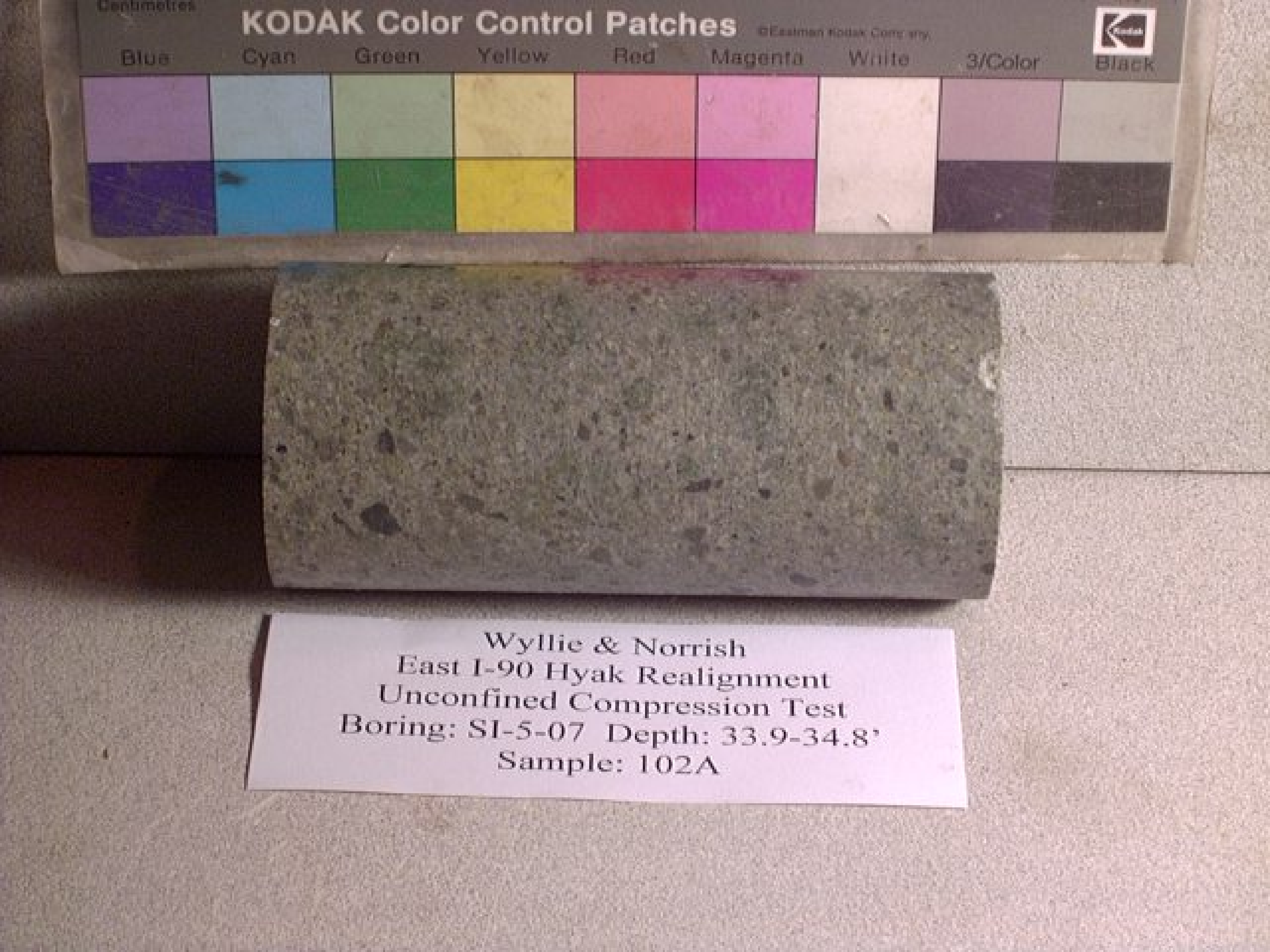

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-9-07 Depth: 42.4-43.1'
Sample: 201


Centimetres
KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-7-07 Depth: 36.9-37.4'
Sample: 101B


KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-7-07 Depth: 36.9-37.4'
Sample: 101B

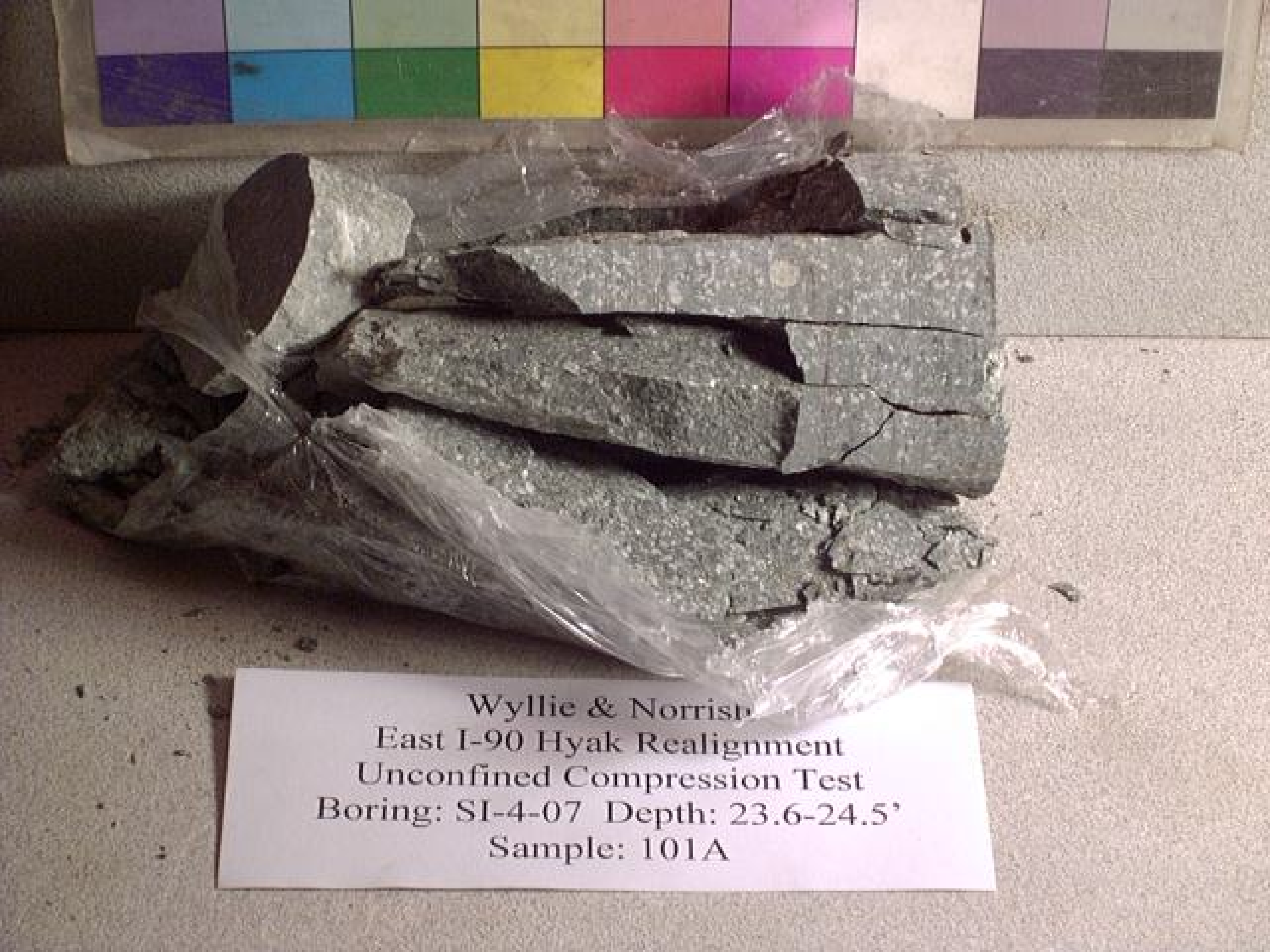

KODAK Color Control Patches
©Eastman Kodak Company
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-5-07 Depth: 56.9-57.6'
Sample: 103

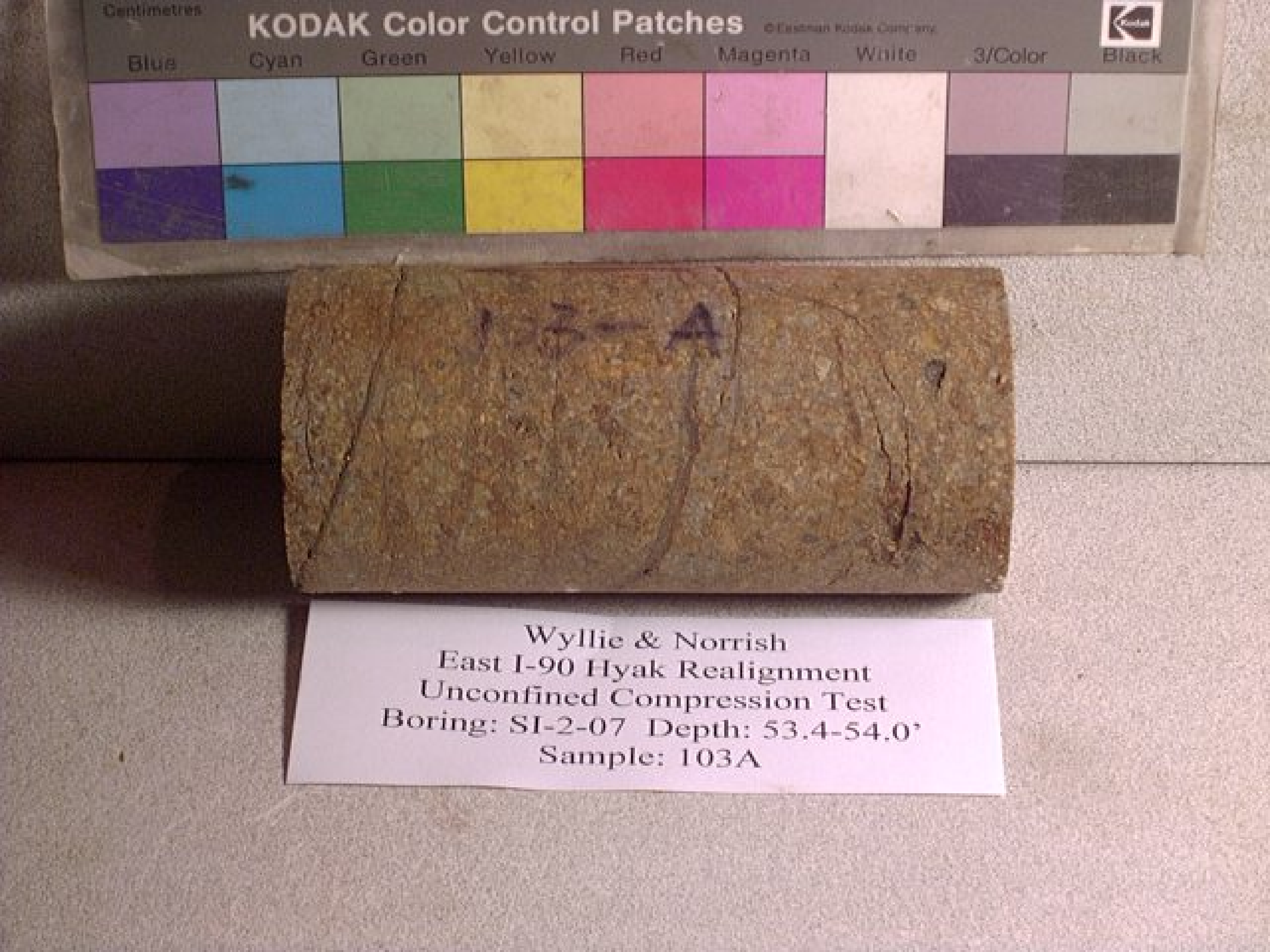

KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
56.9
#103
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-5-07 Depth: 56.9-57.6'
Sample: 103

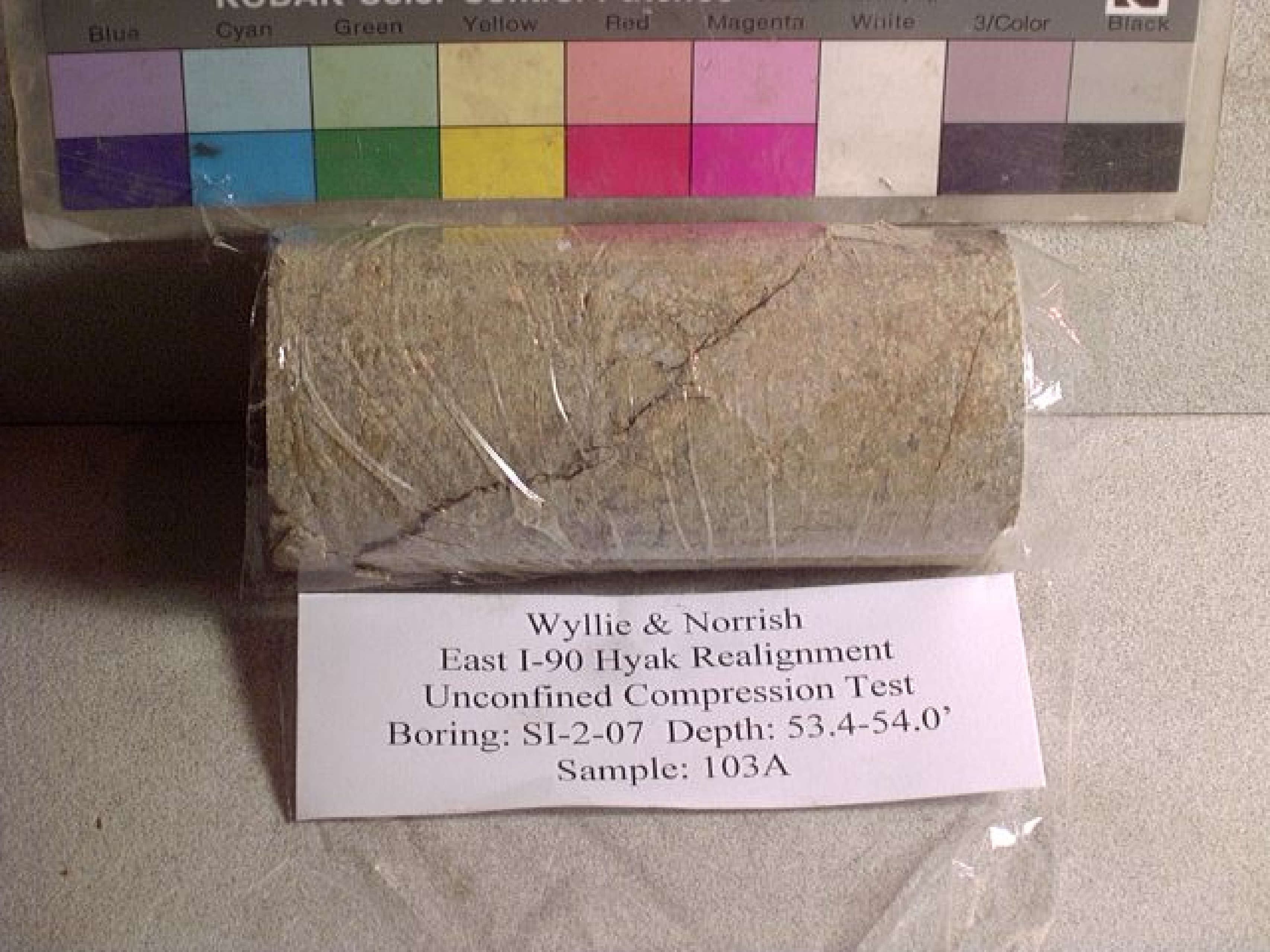

KODAK Color Control Patches
©Eastman Kodak Company
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-5-07 Depth: 33.9-34.8'
Sample: 102A


KODAK Color Control Patches
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-5-07 Depth: 33.9-34.8'
Sample: 102A


Centimetres
KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-4-07 Depth: 23.6-24.5'
Sample: 101A

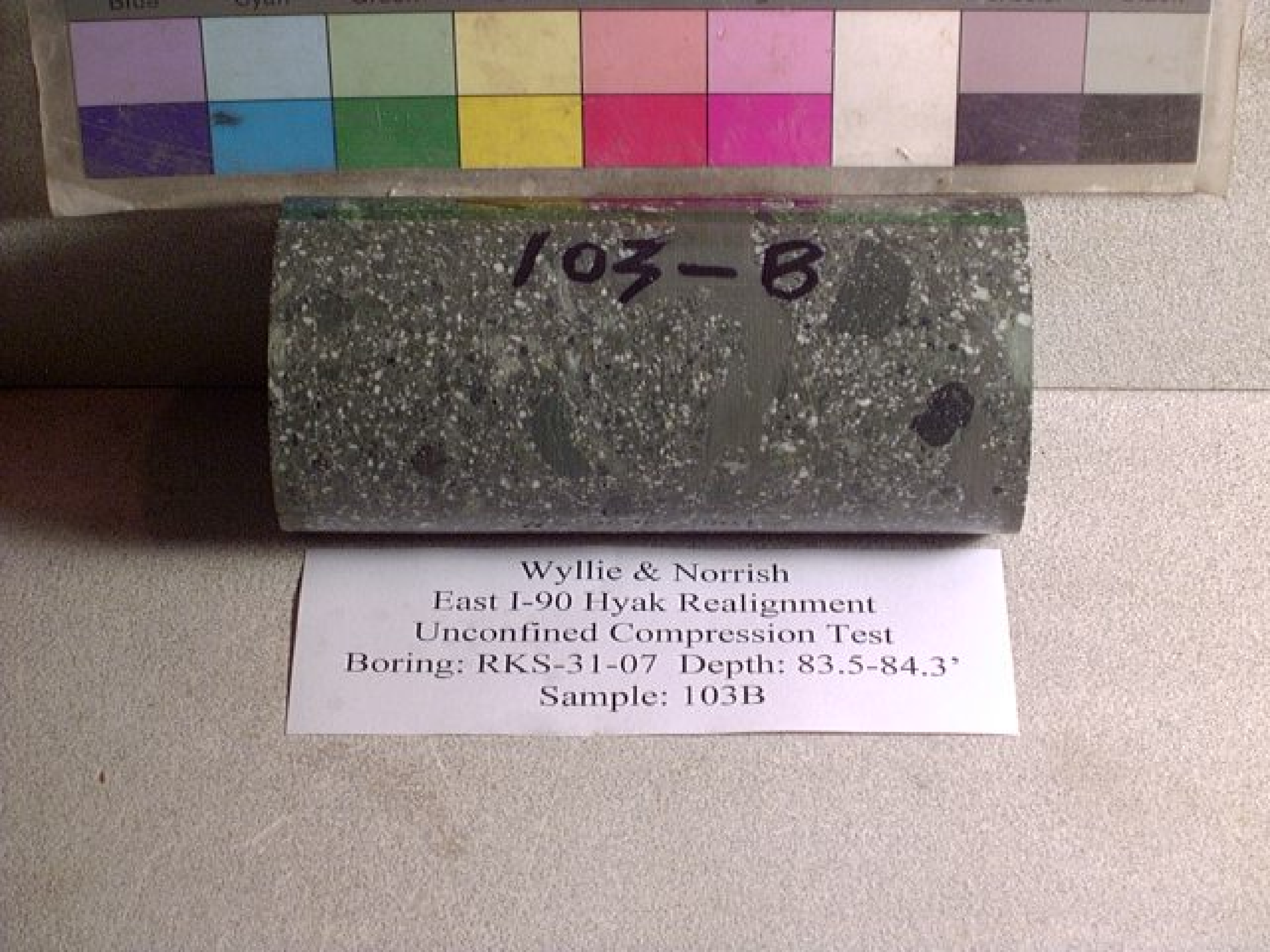

Wyllie & Norris
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-4-07 Depth: 23.6-24.5'
Sample: 101A


Centimetres
KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-2-07 Depth: 53.4-54.0'
Sample: 103A

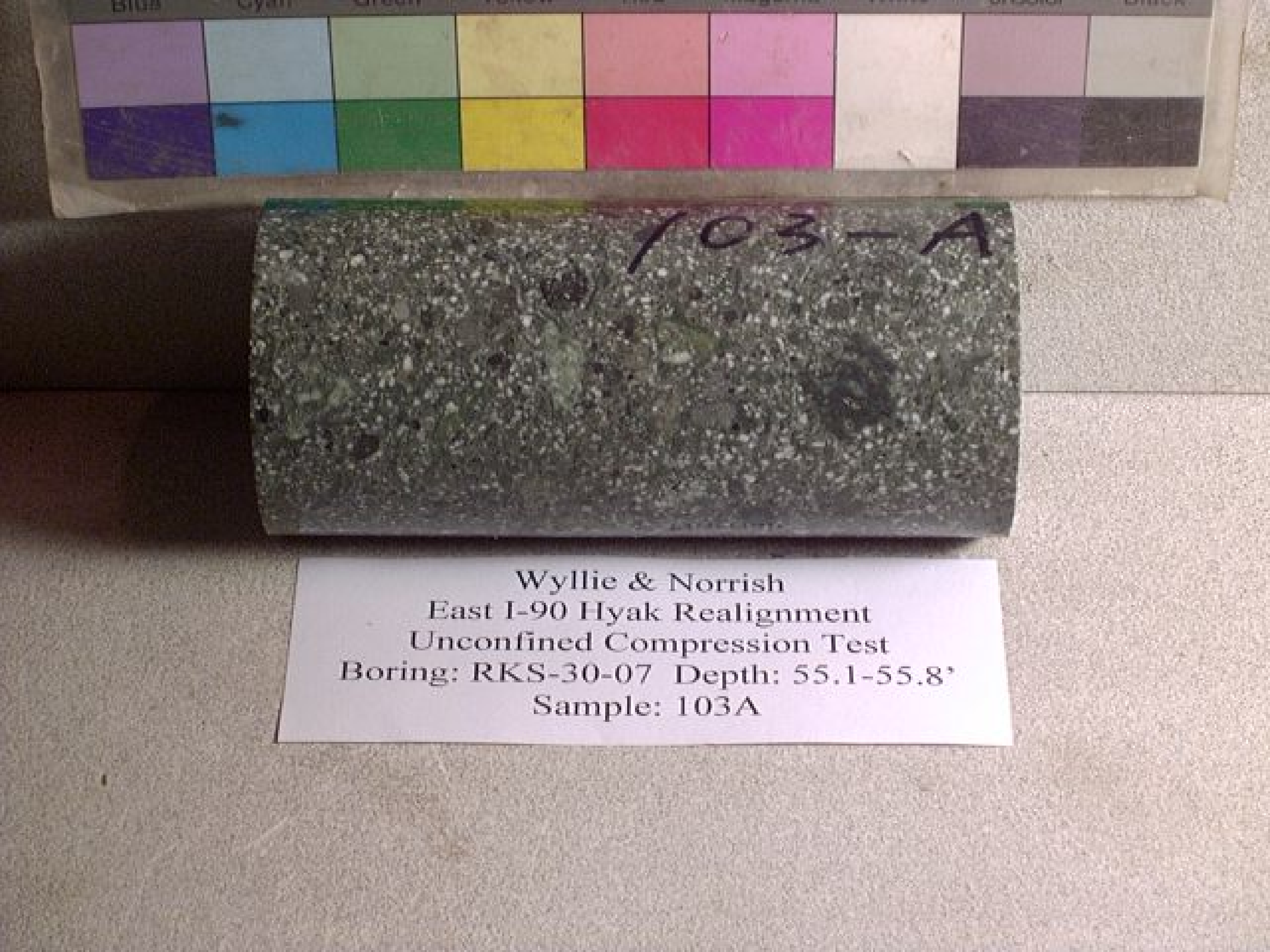

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-2-07 Depth: 53.4-54.0'
Sample: 103A


Centimetres
KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-1-07 Depth: 32.0-32.7'
Sample: 101

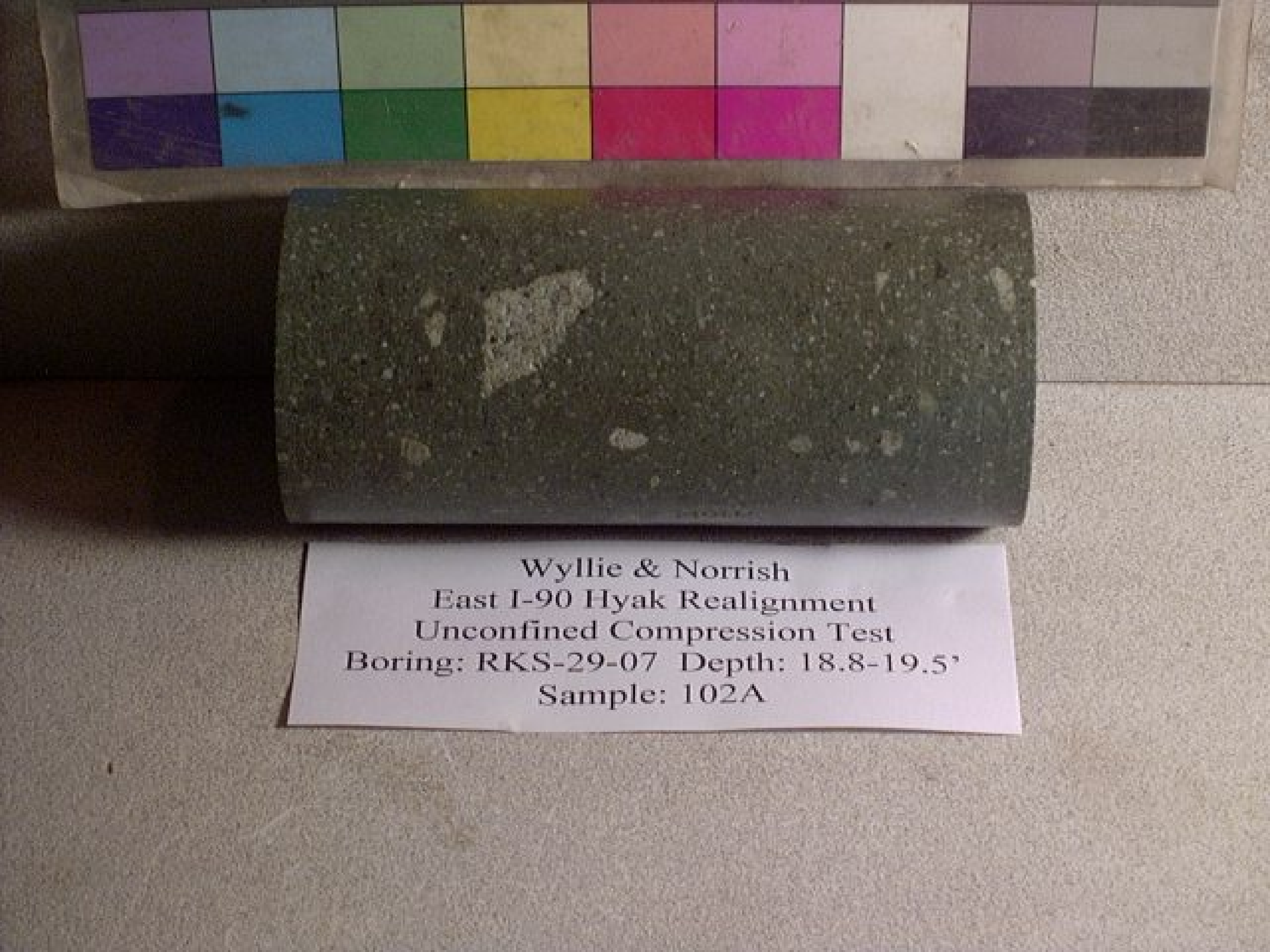

KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: SI-1-07 Depth: 32.0-32.7'
Sample: 101

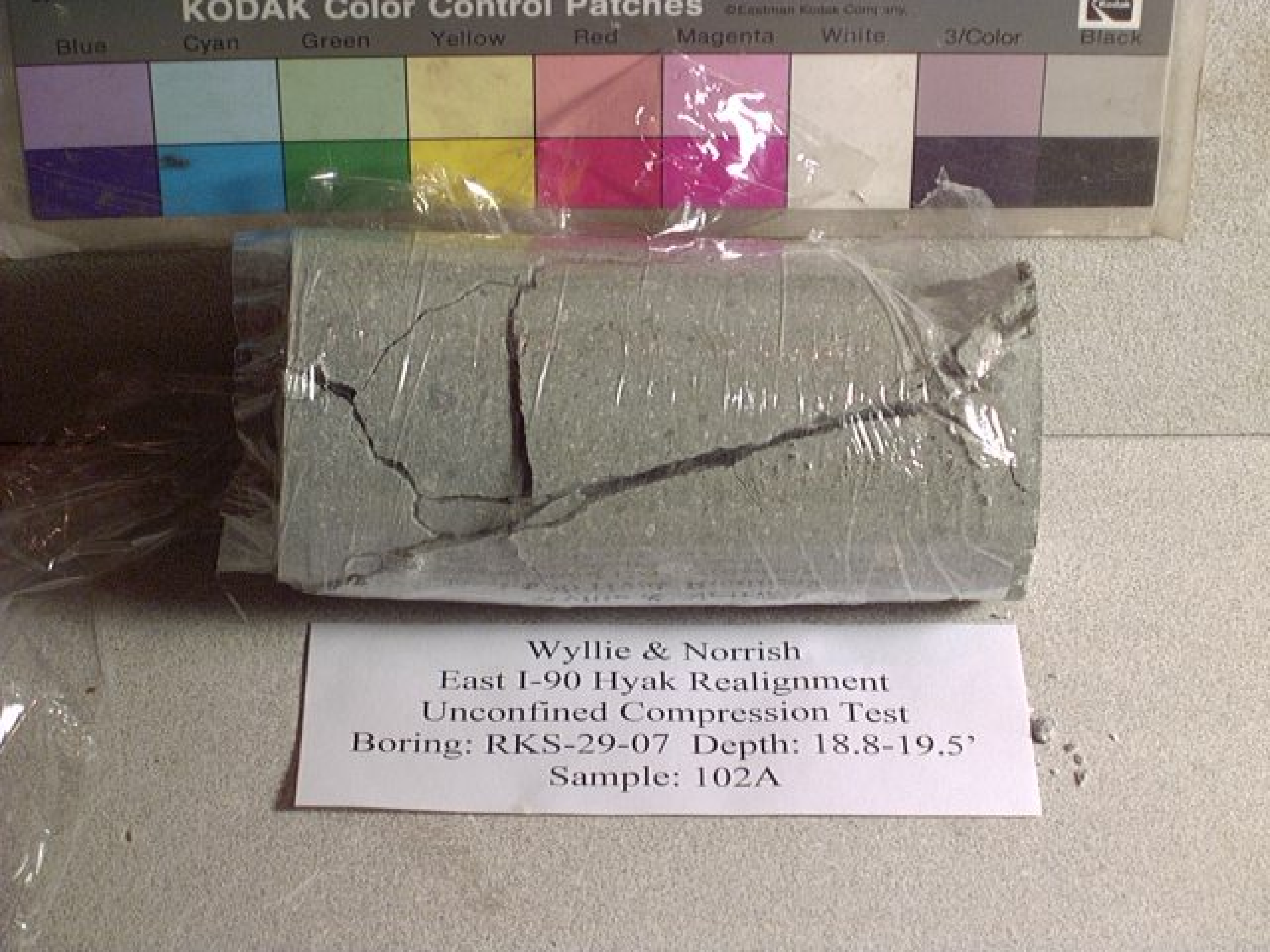

103-B
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-31-07 Depth: 83.5-84.3'
Sample: 103B

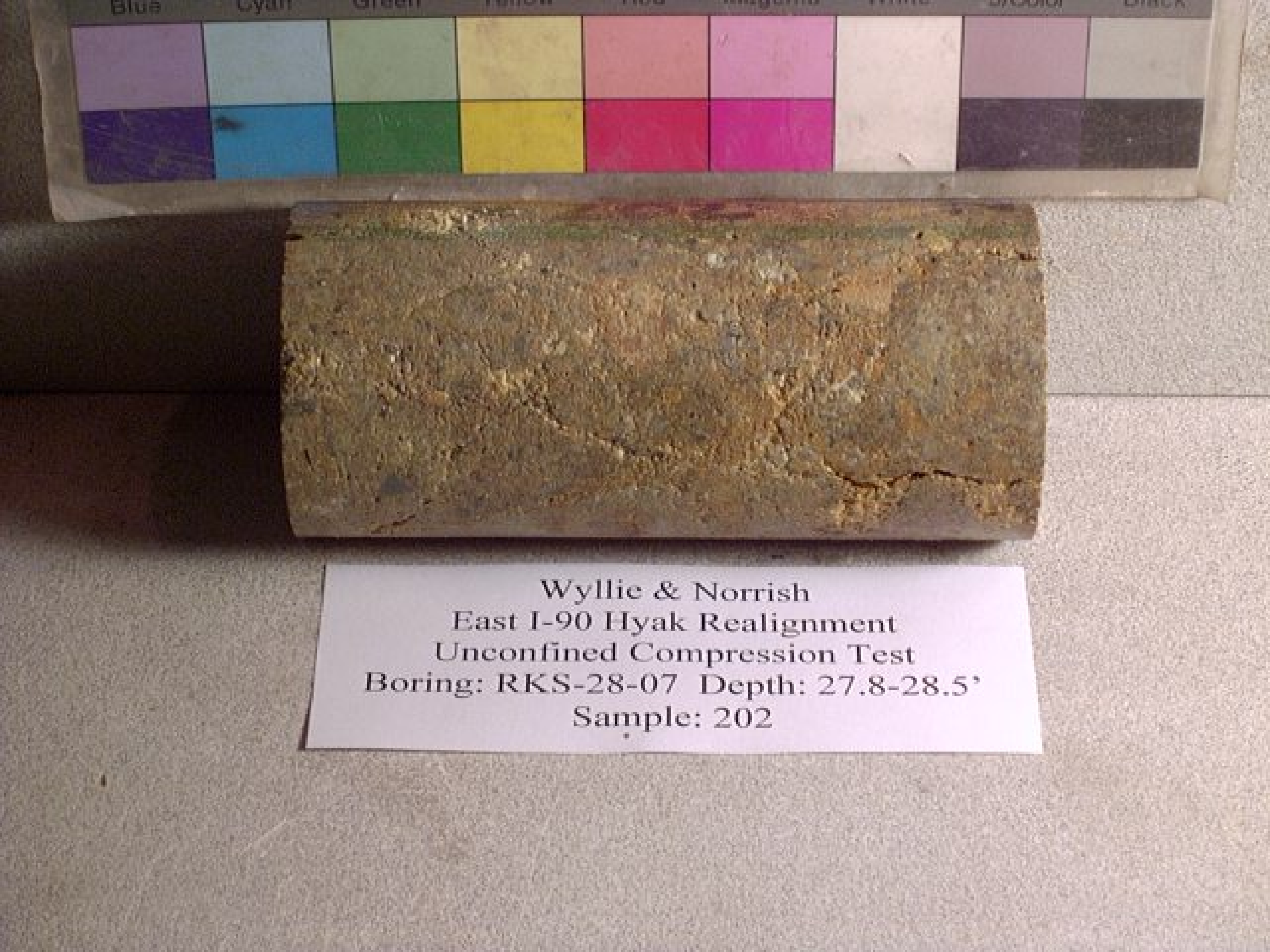

KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-31-07 Depth: 83.5-84.3'
Sample: 103B


103-A
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-30-07 Depth: 55.1-55.8'
Sample: 103A

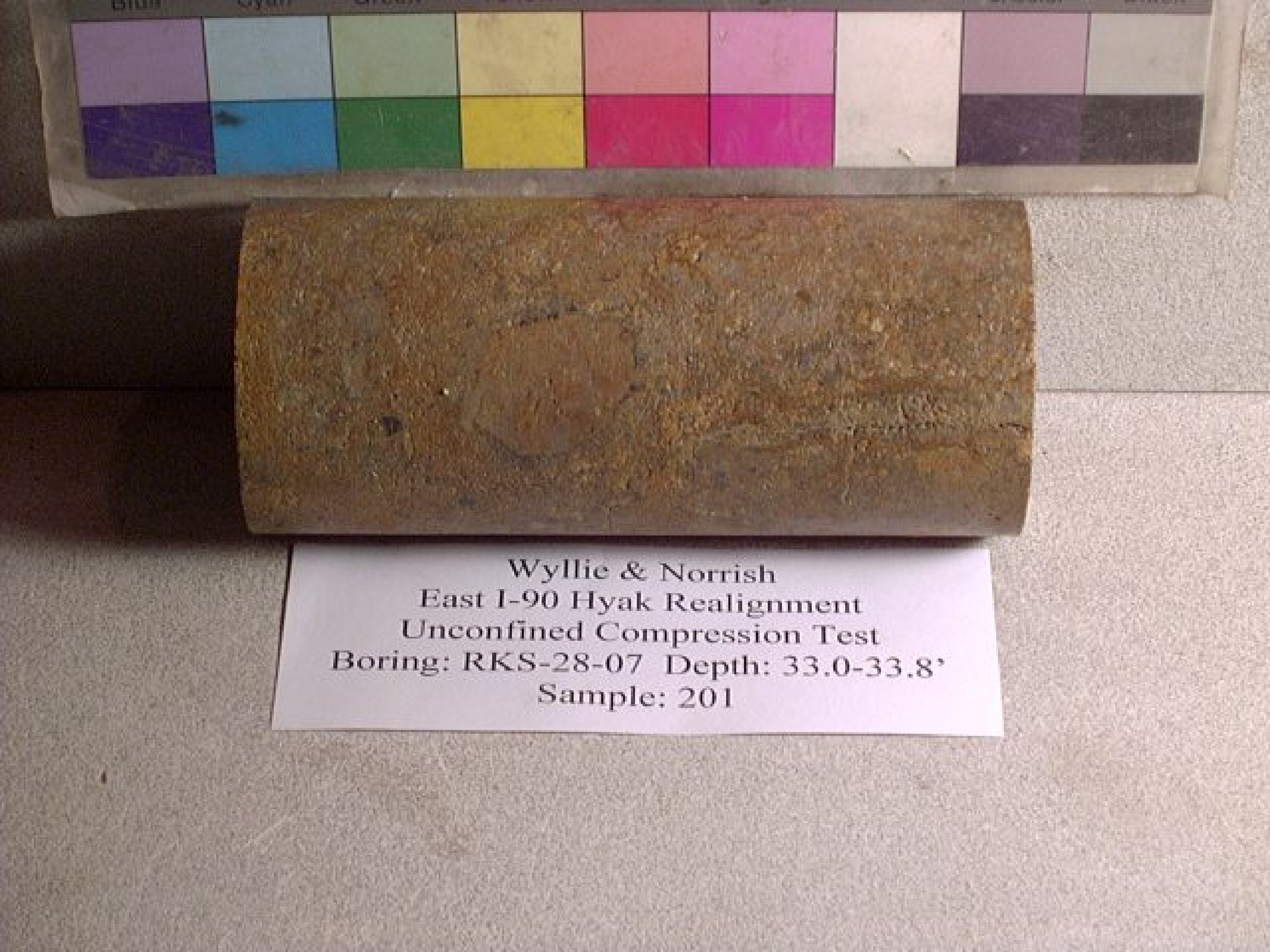

KODAK Color Control Patches
Blue Cyan Green Yellow Red Magenta White 3/Color Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-30-07 Depth: 55.1-55.8'
Sample: 103A


Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-29-07 Depth: 18.8-19.5'
Sample: 102A

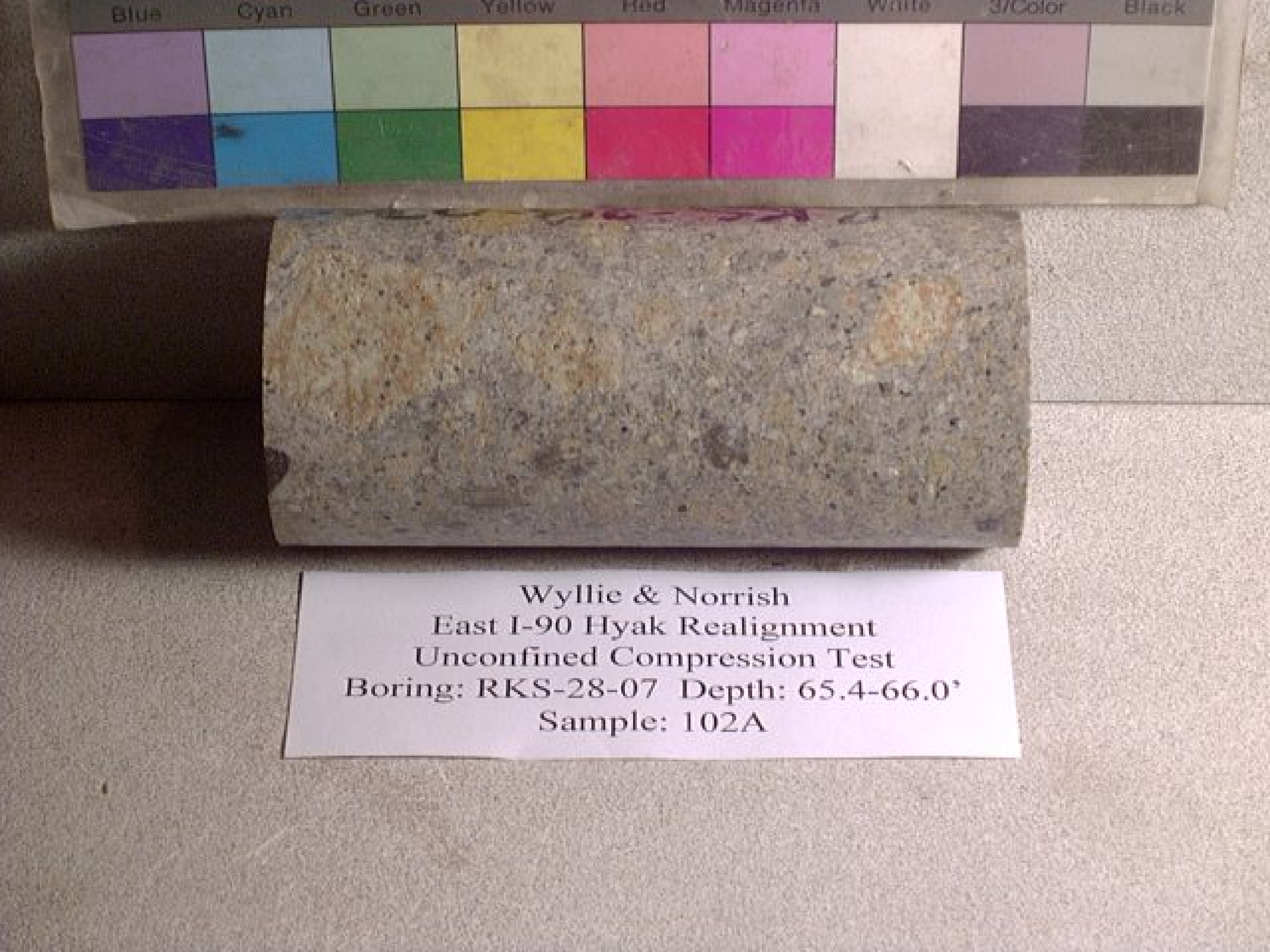

KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-29-07 Depth: 18.8-19.5'
Sample: 102A

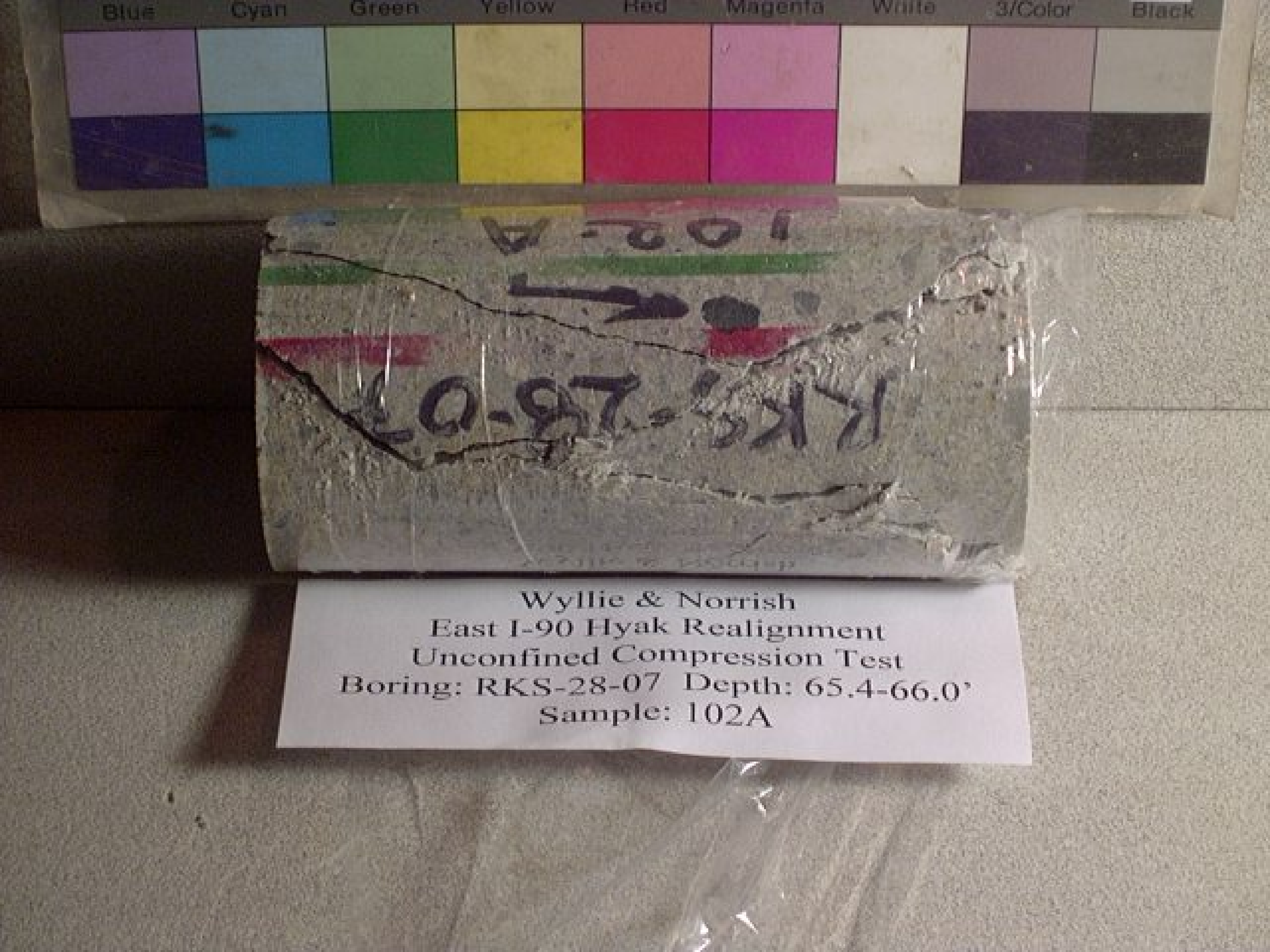

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-28-07 Depth: 27.8-28.5'
Sample: 202

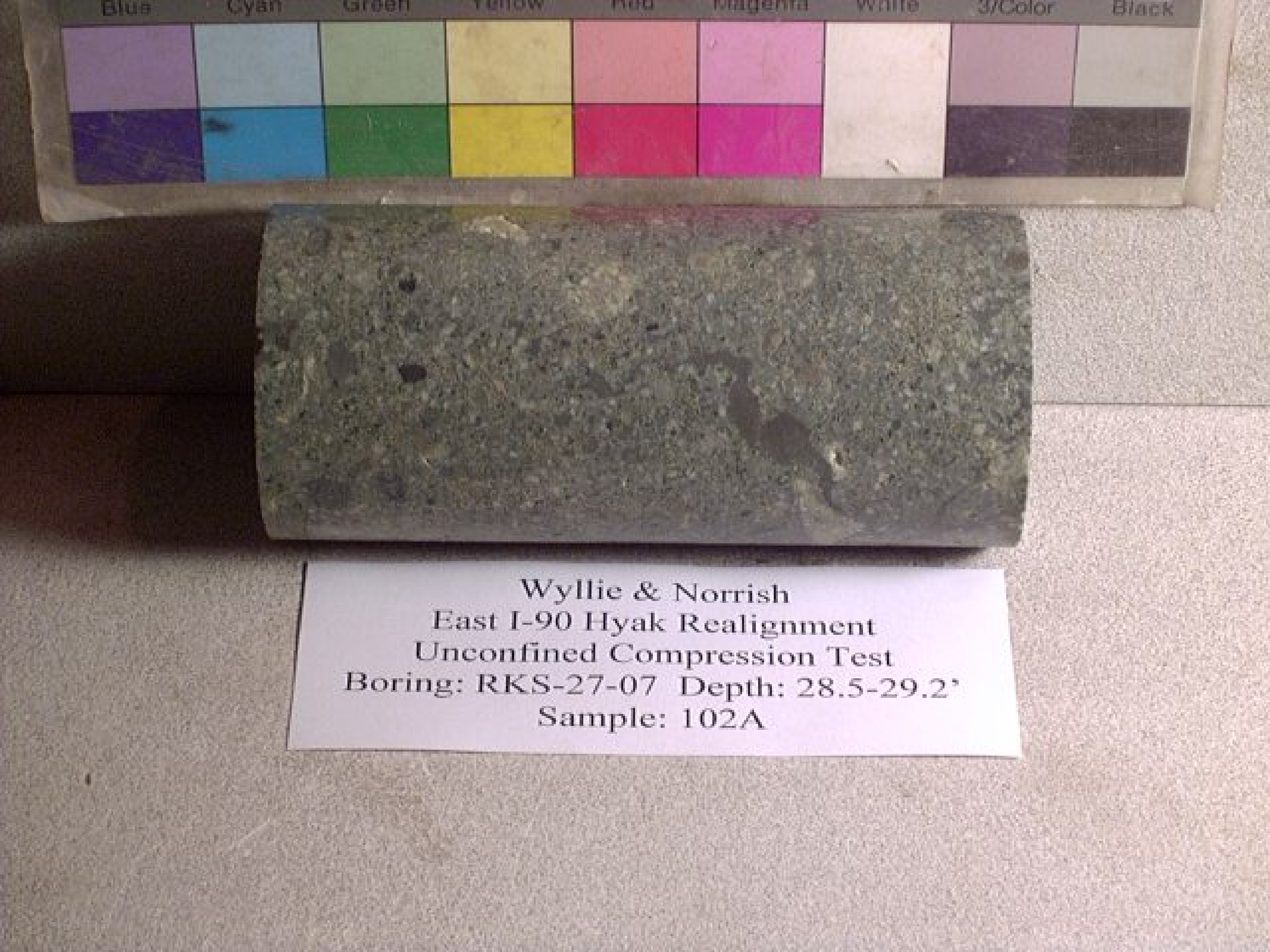

KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-28-07 Depth: 27.8-28.5'
Sample: 202

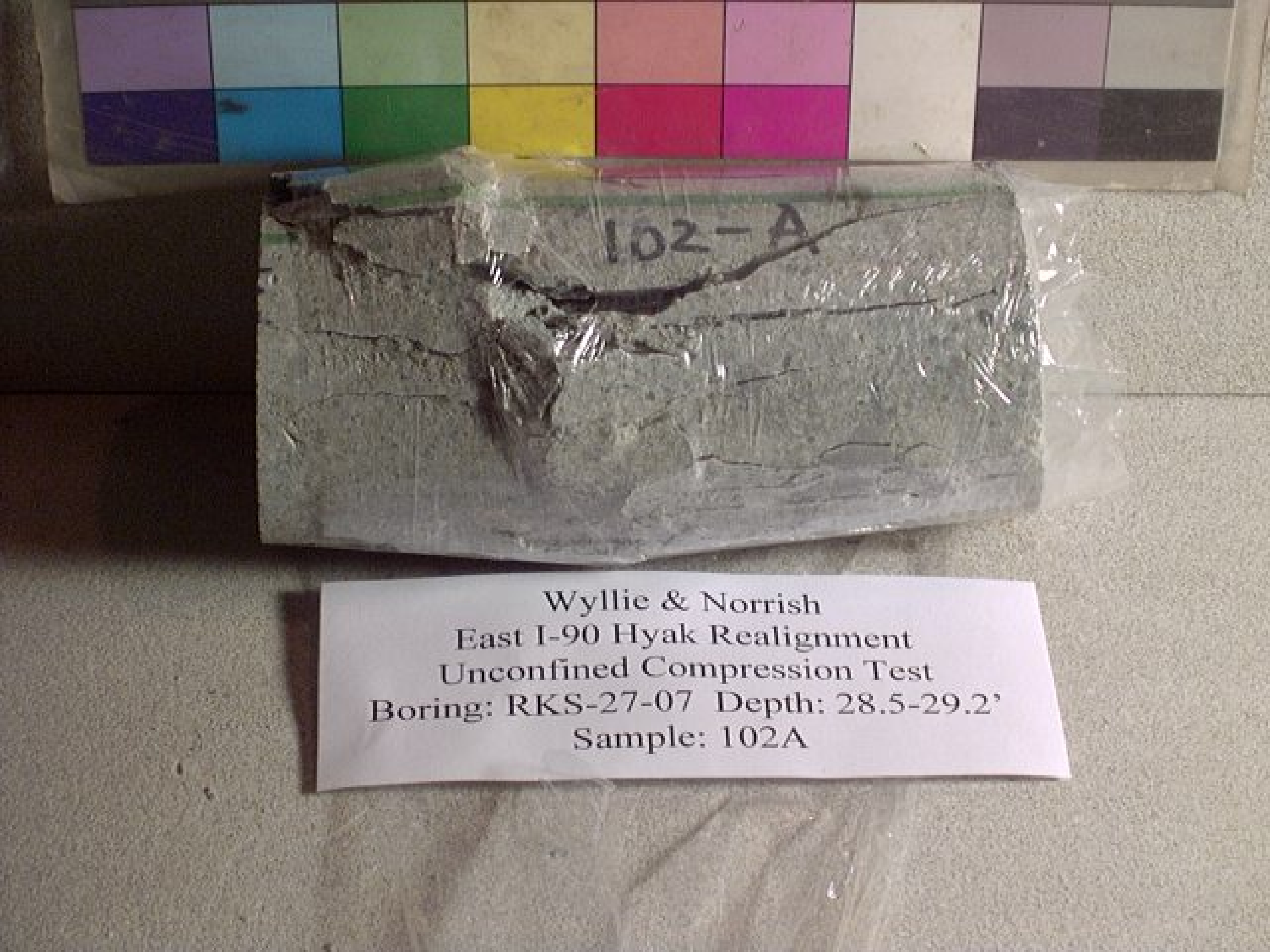

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-28-07 Depth: 33.0-33.8'
Sample: 201

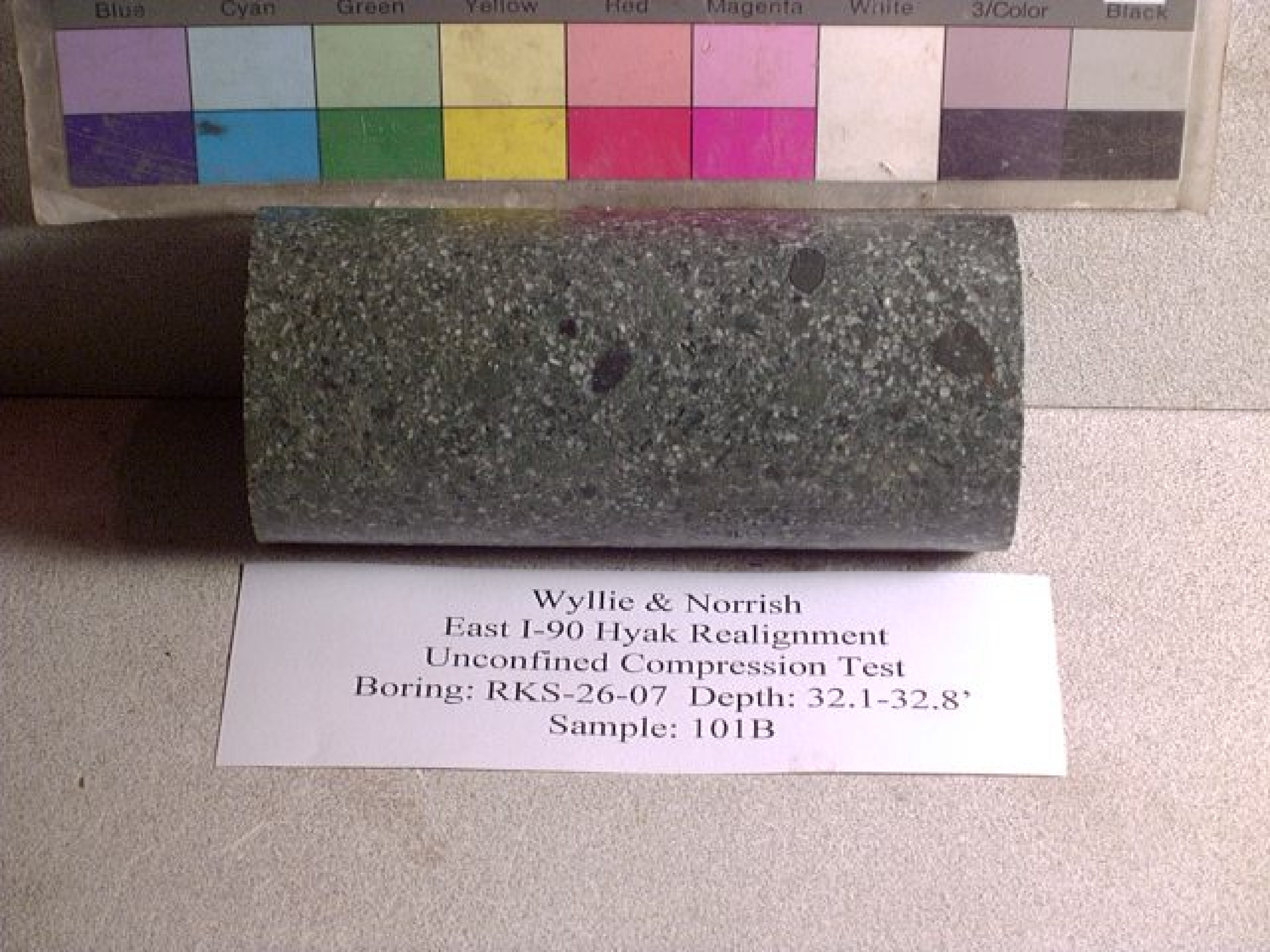

KODAK Color Control Patches
©Eastman Kodak Company
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-28-07 Depth: 33.0-33.8’
Sample: 201

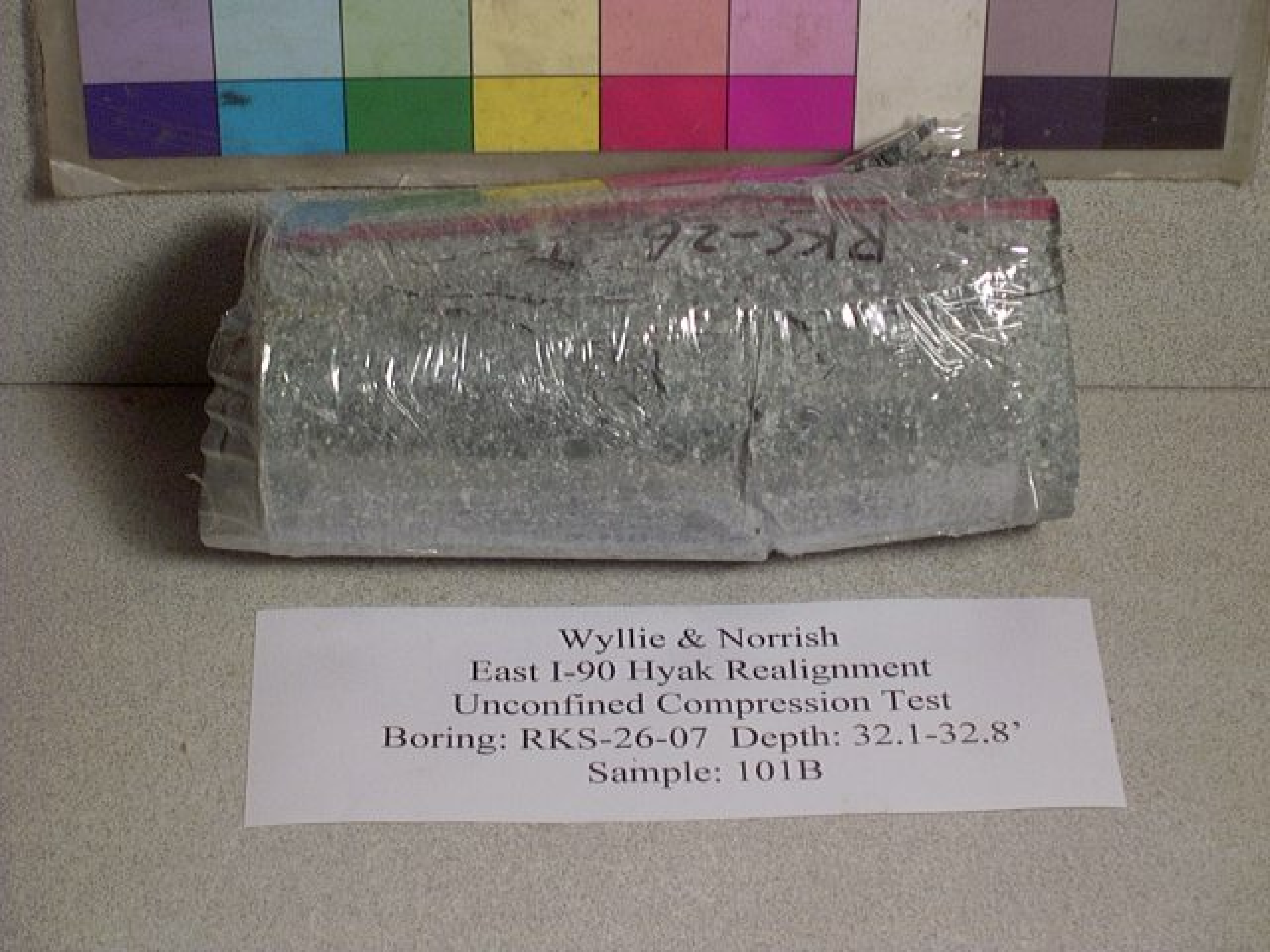

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-28-07 Depth: 65.4-66.0'
Sample: 102A

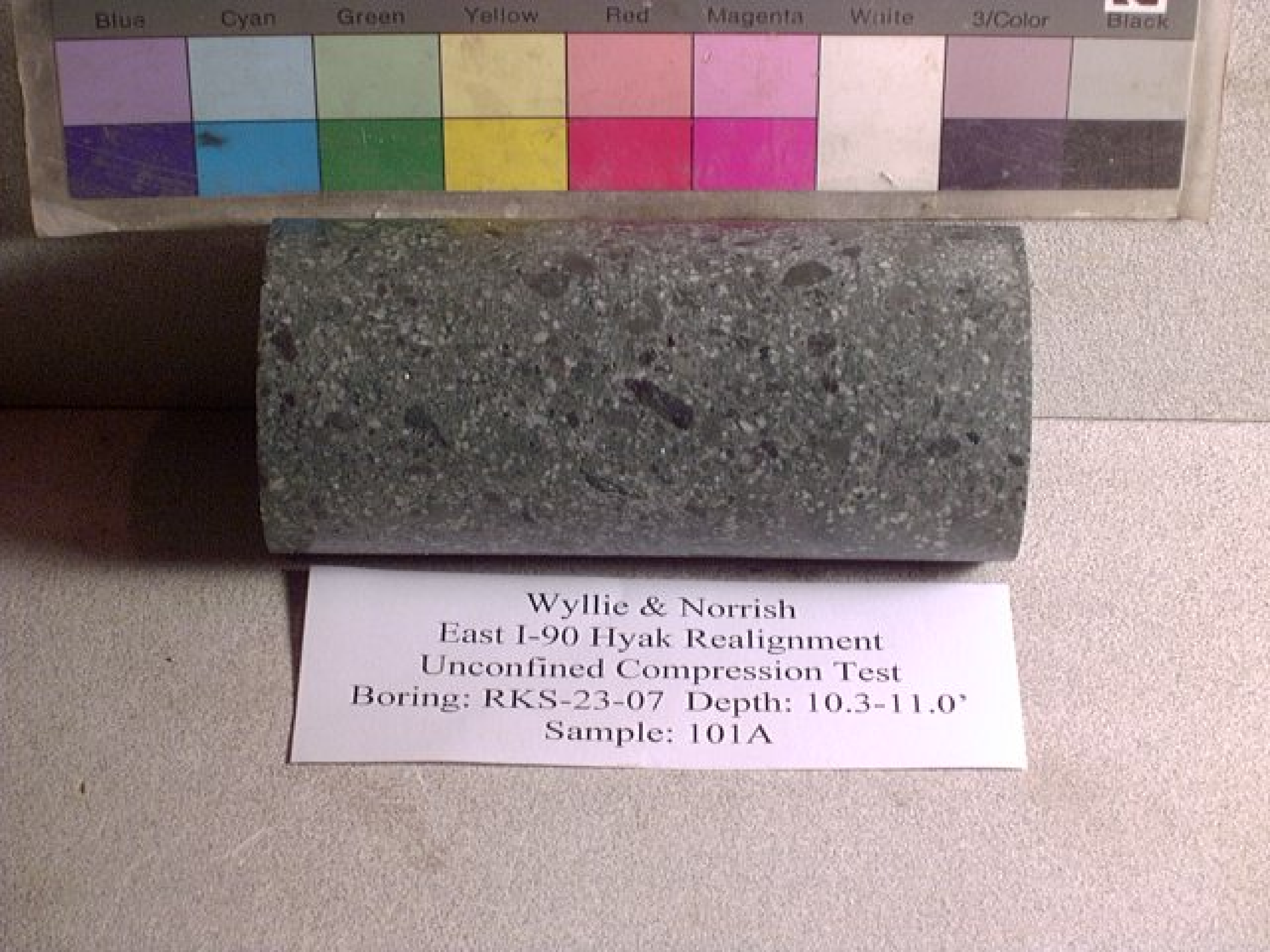

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-28-07 Depth: 65.4-66.0’
Sample: 102A


Blue
Cyan
Green
Magenta
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-27-07 Depth: 28.5-29.2'
Sample: 102A

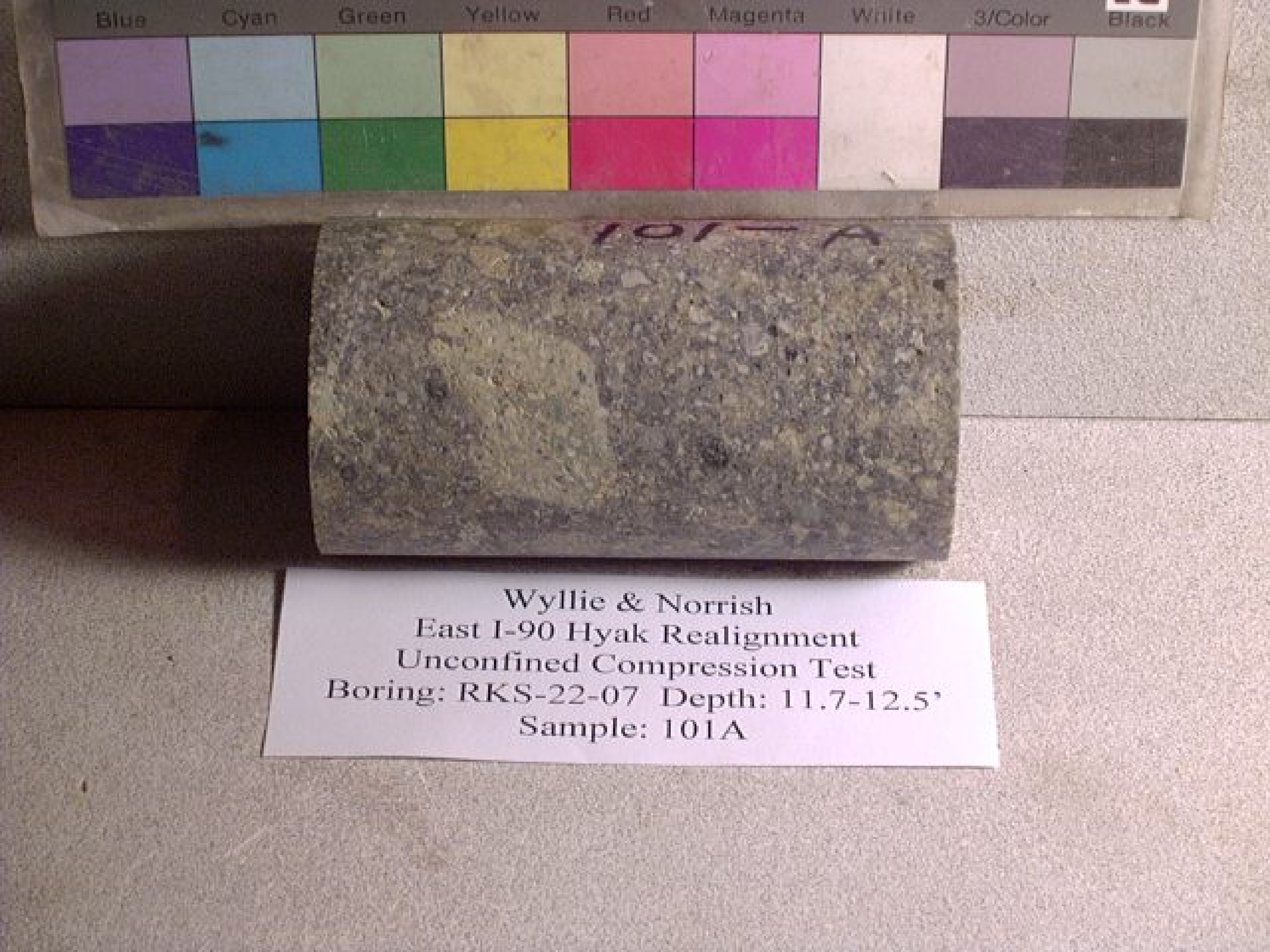

102-A
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-27-07 Depth: 28.5-29.2'
Sample: 102A

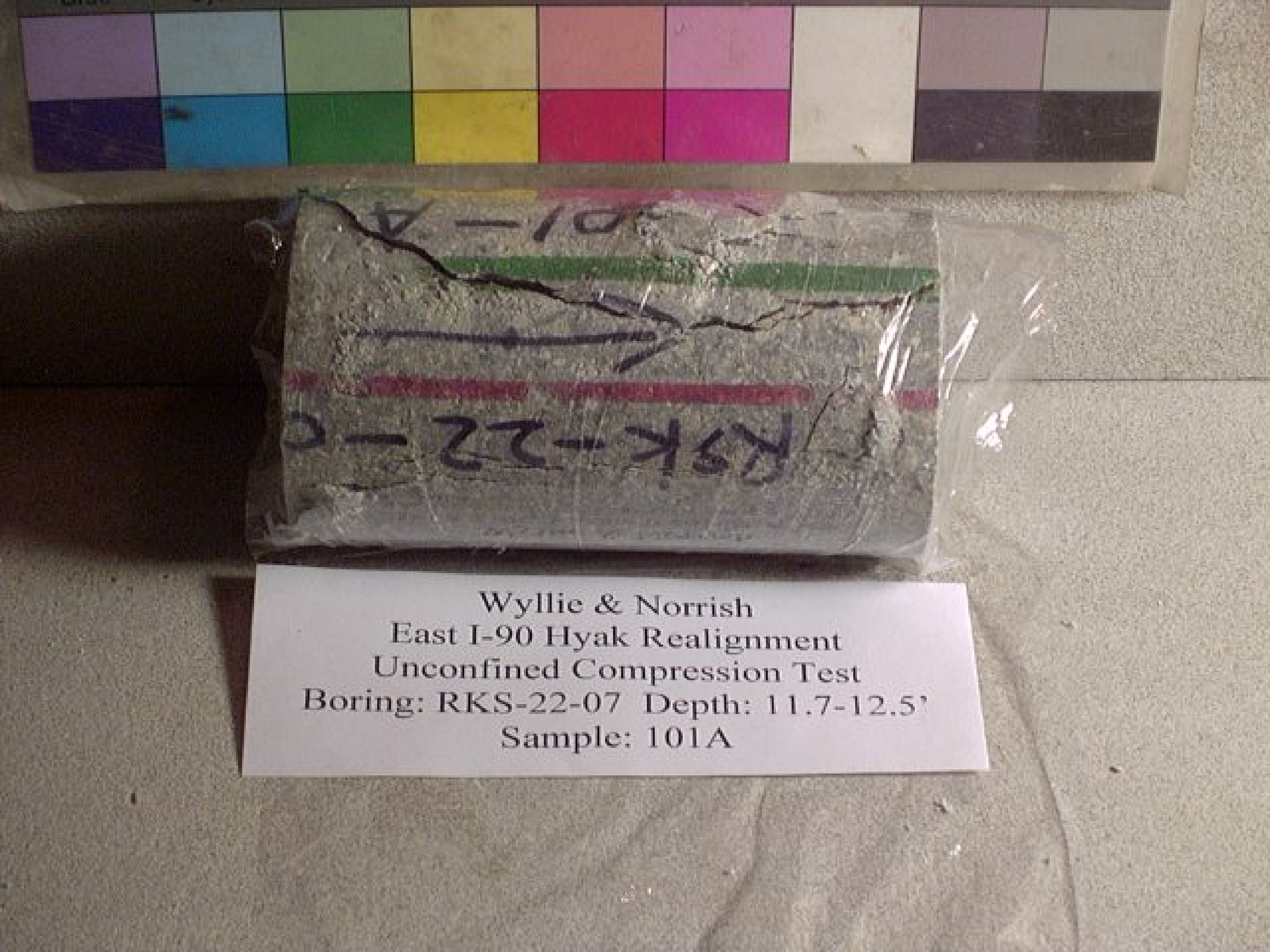

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-26-07 Depth: 32.1-32.8'
Sample: 101B

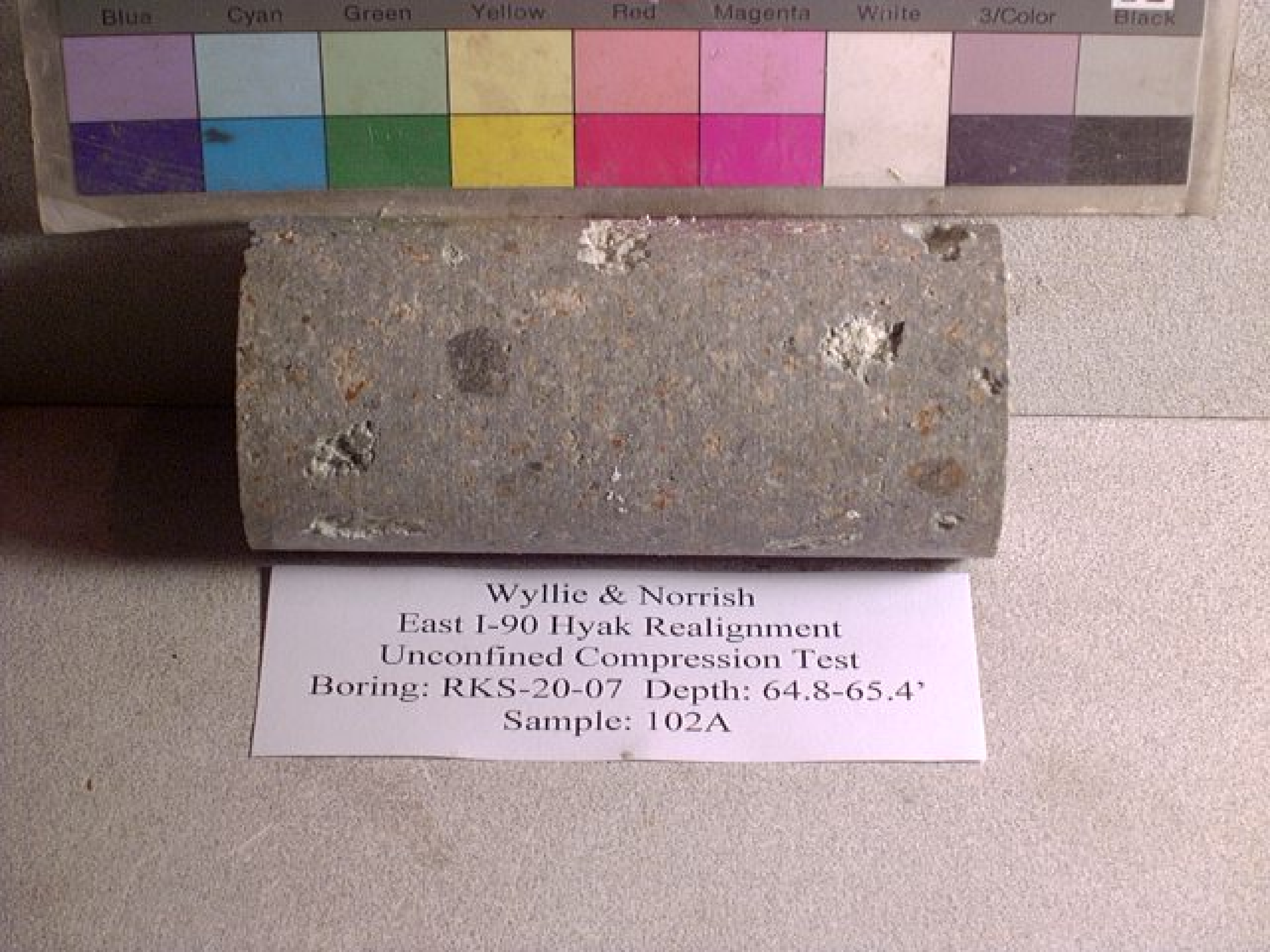

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-26-07 Depth: 32.1-32.8'
Sample: 101B

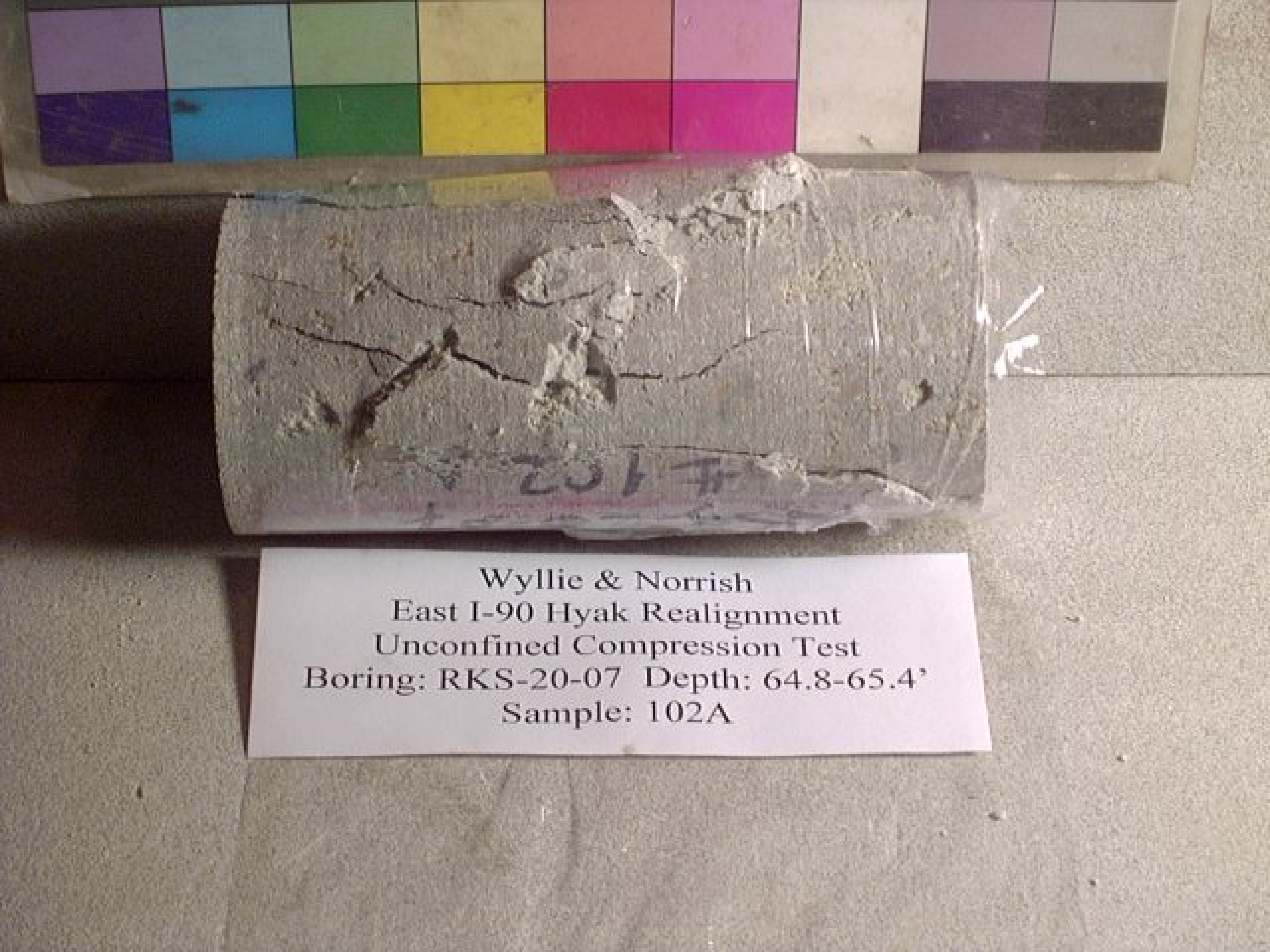

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-23-07 Depth: 10.3-11.0'
Sample: 101A

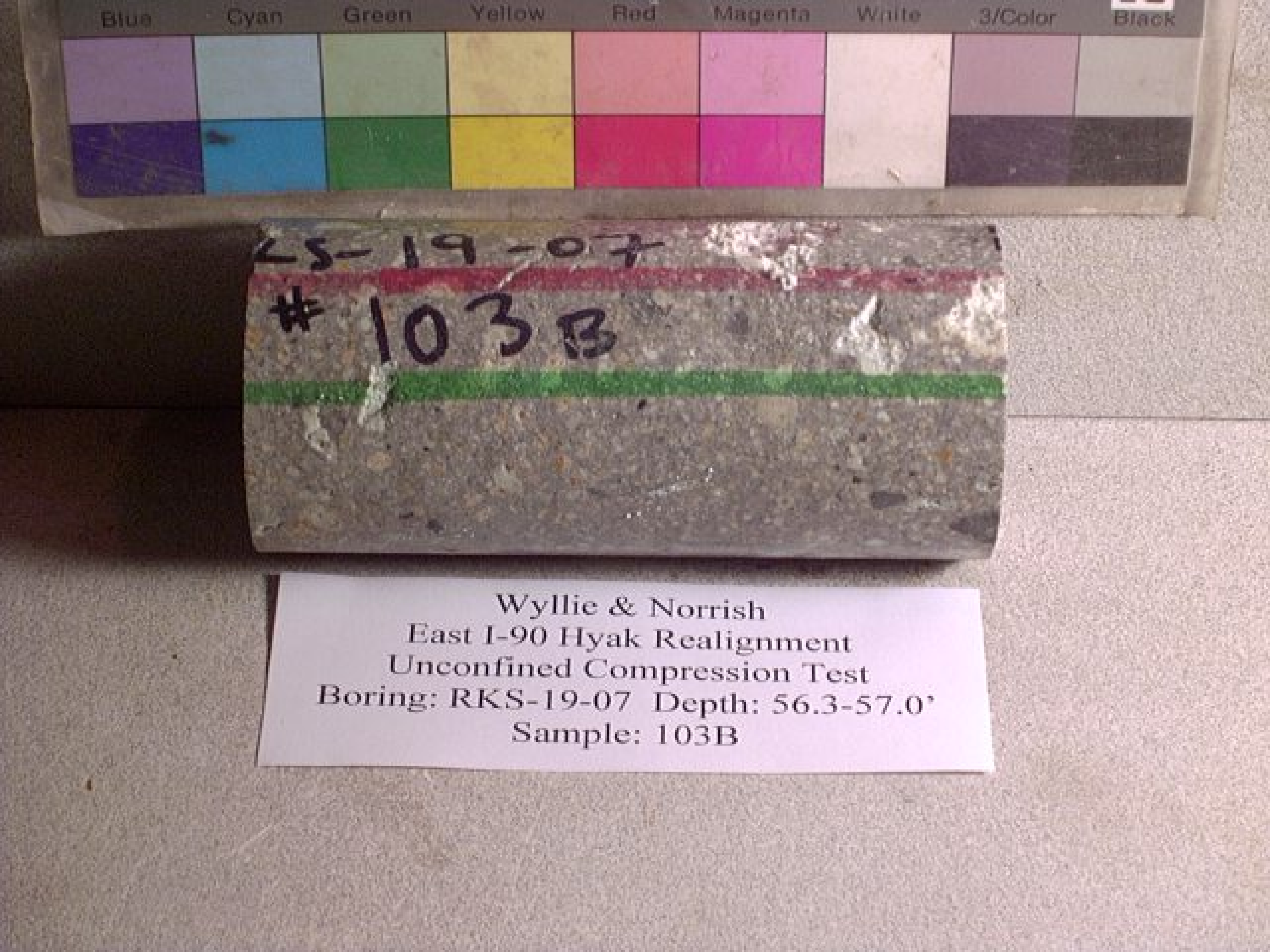

KODAK
Cyan
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-23-07 Depth: 10.3-11.0'
Sample: 101A

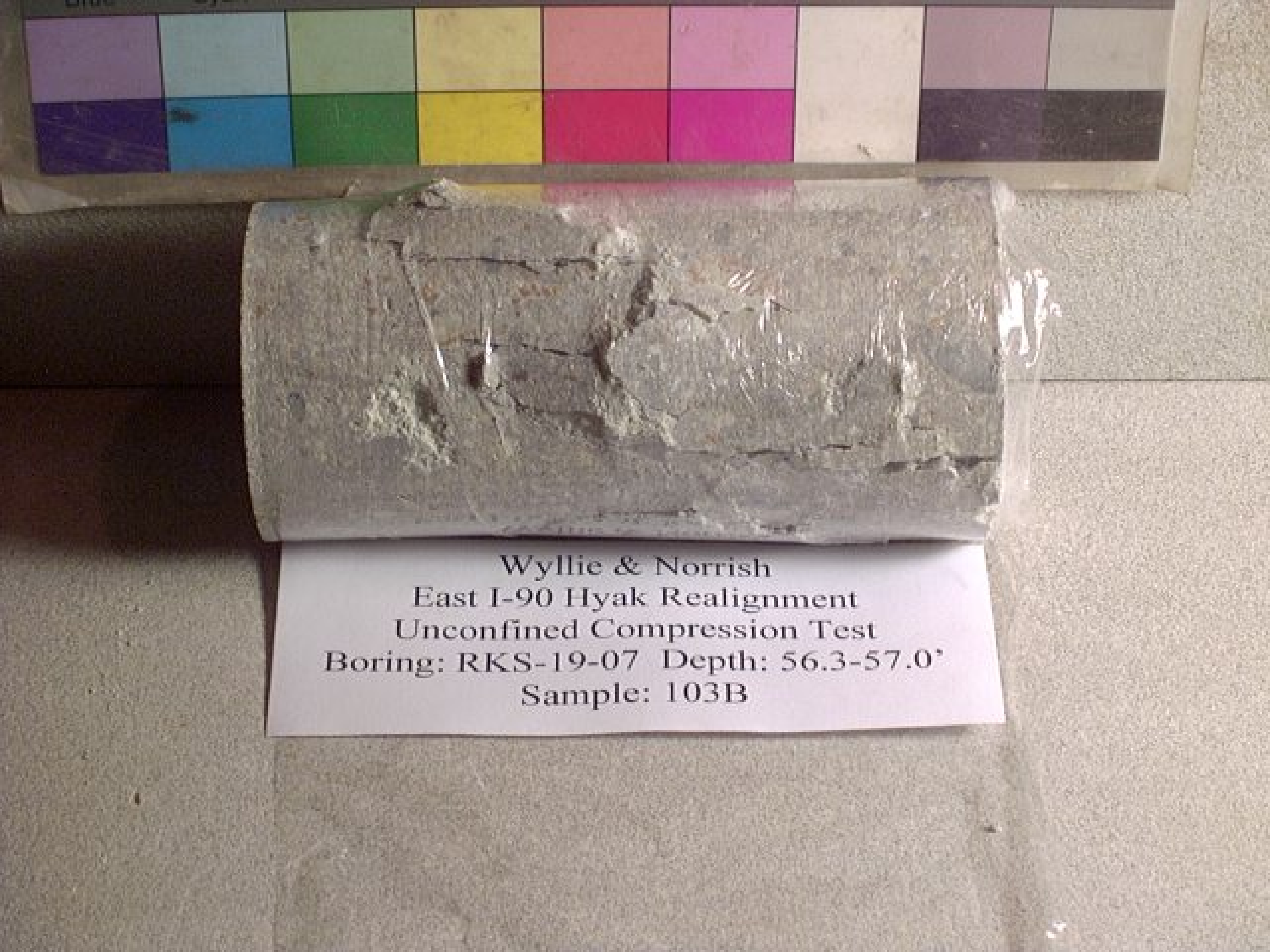

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
101-A
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-22-07 Depth: 11.7-12.5'
Sample: 101A

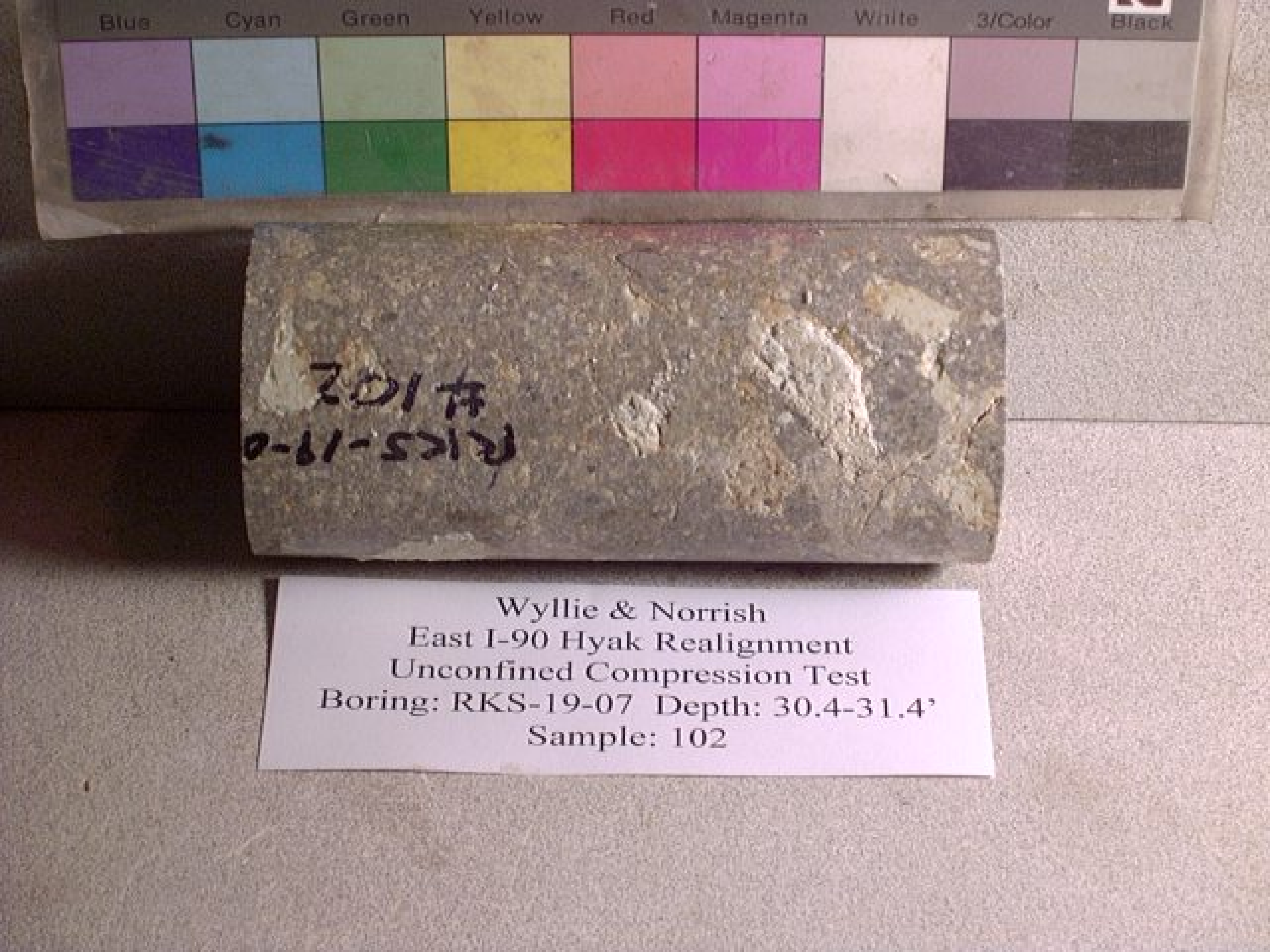

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-22-07 Depth: 11.7-12.5'
Sample: 101A

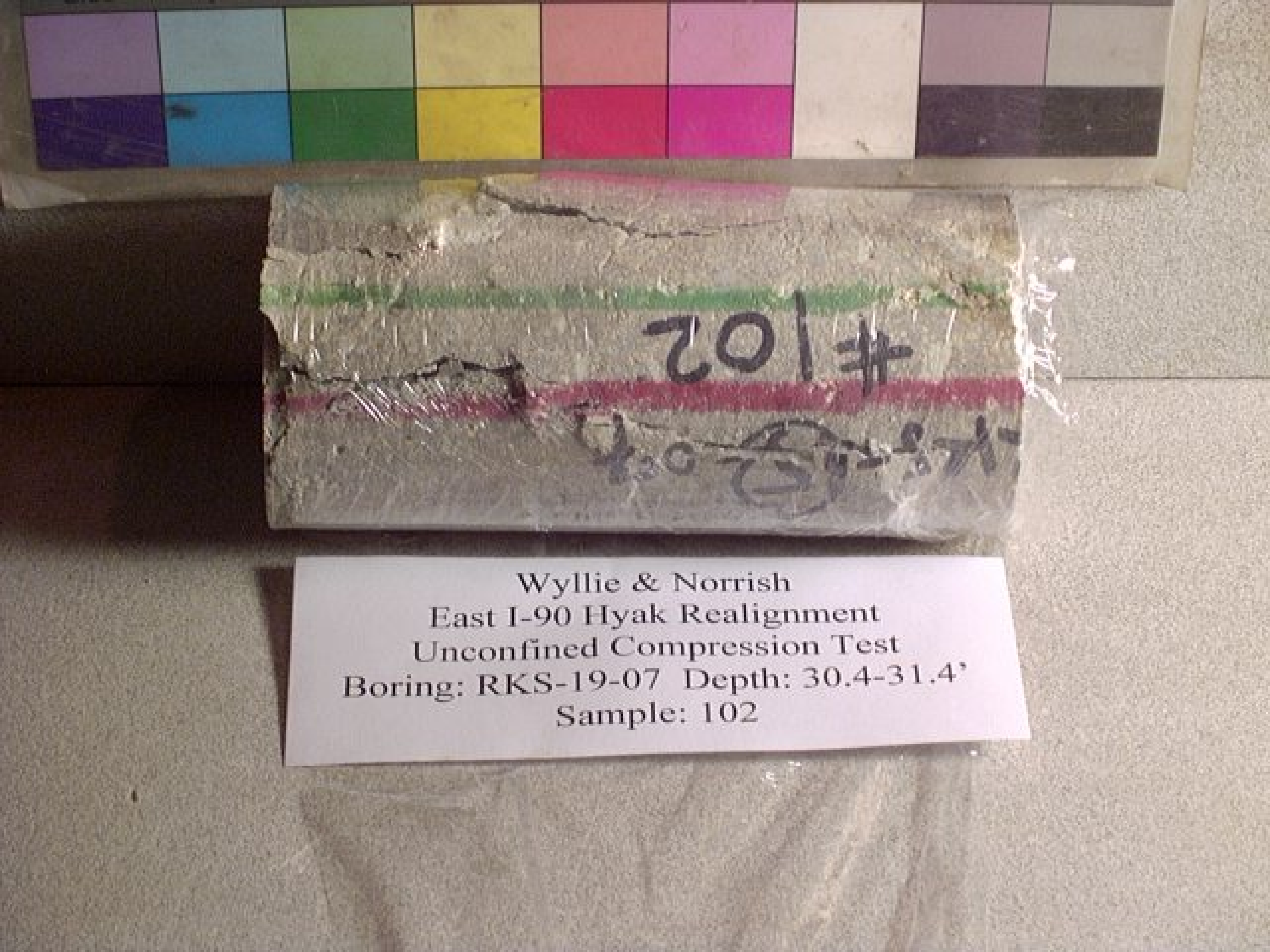

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-20-07 Depth: 64.8-65.4'
Sample: 102A

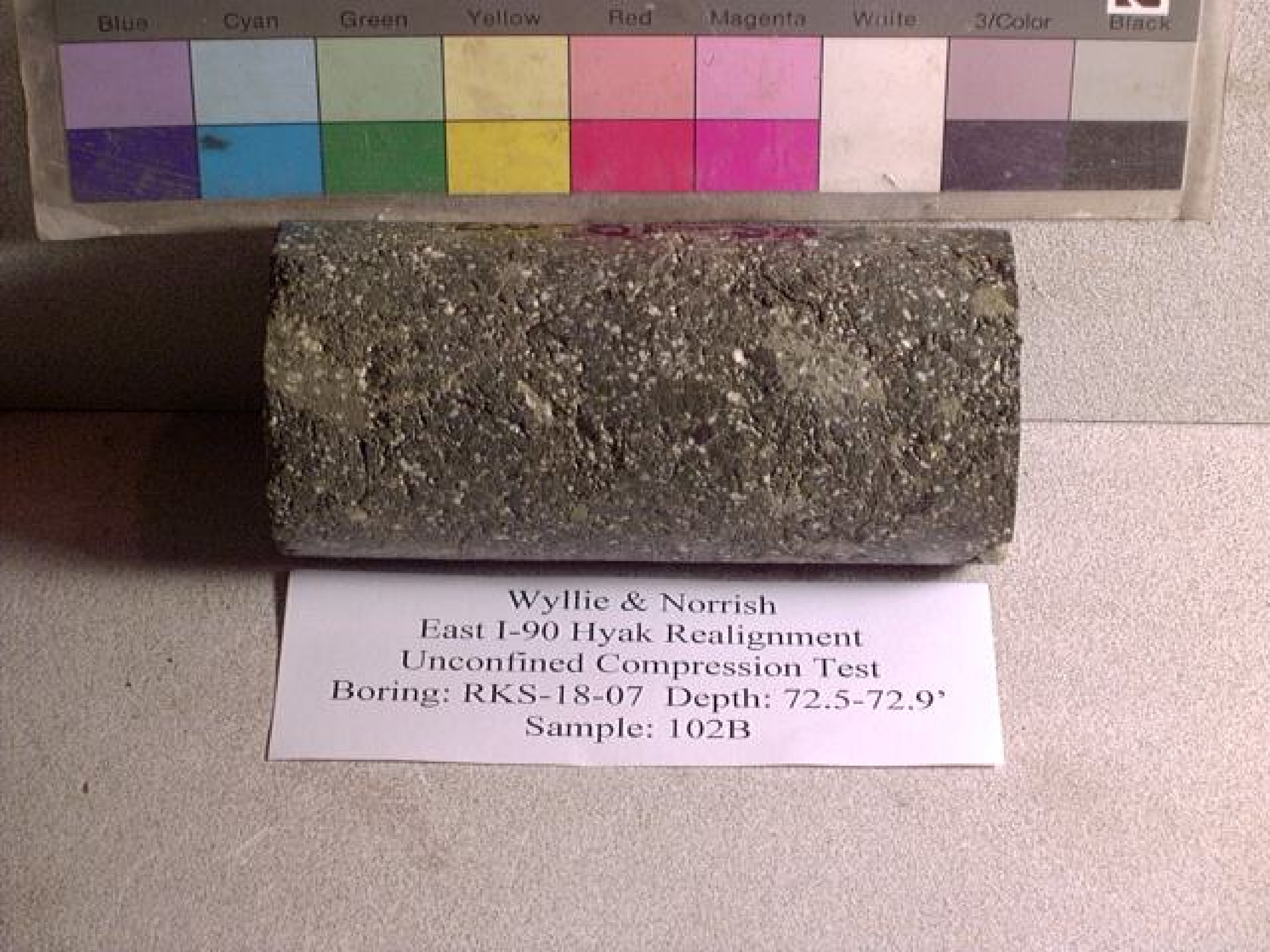

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-20-07 Depth: 64.8-65.4’
Sample: 102A

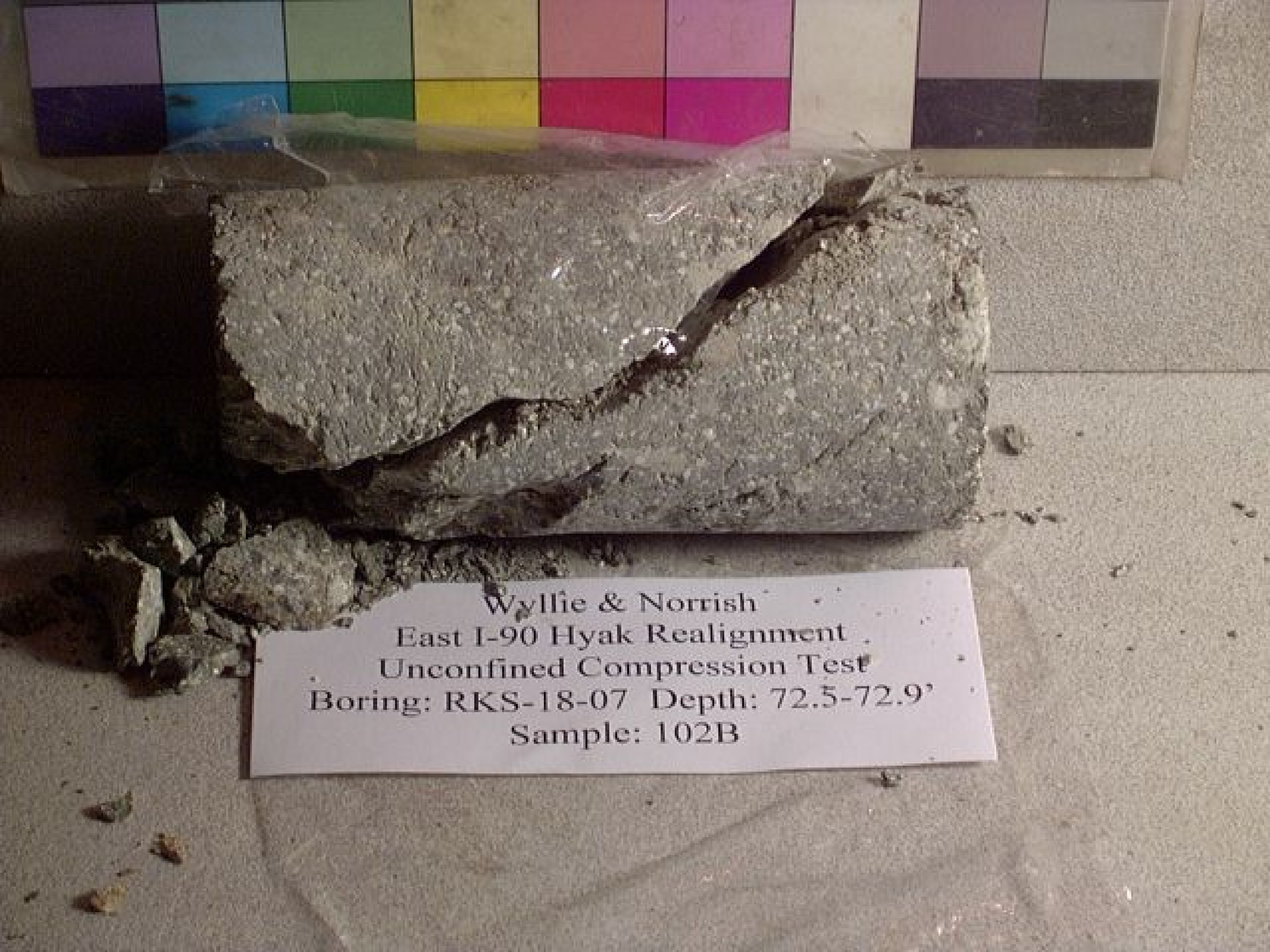

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
#103B
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-19-07 Depth: 56.3-57.0’
Sample: 103B

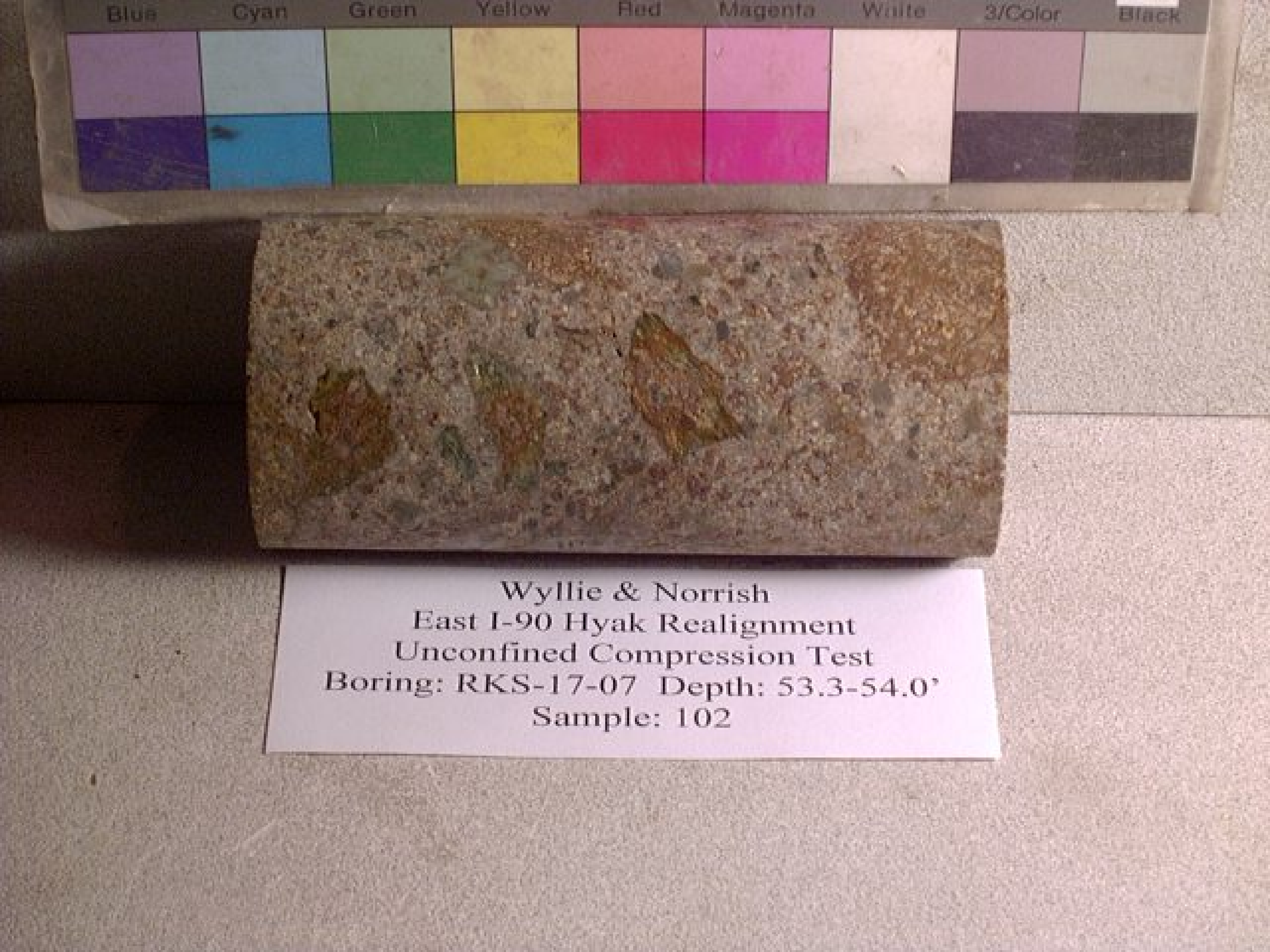

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-19-07 Depth: 56.3-57.0'
Sample: 103B

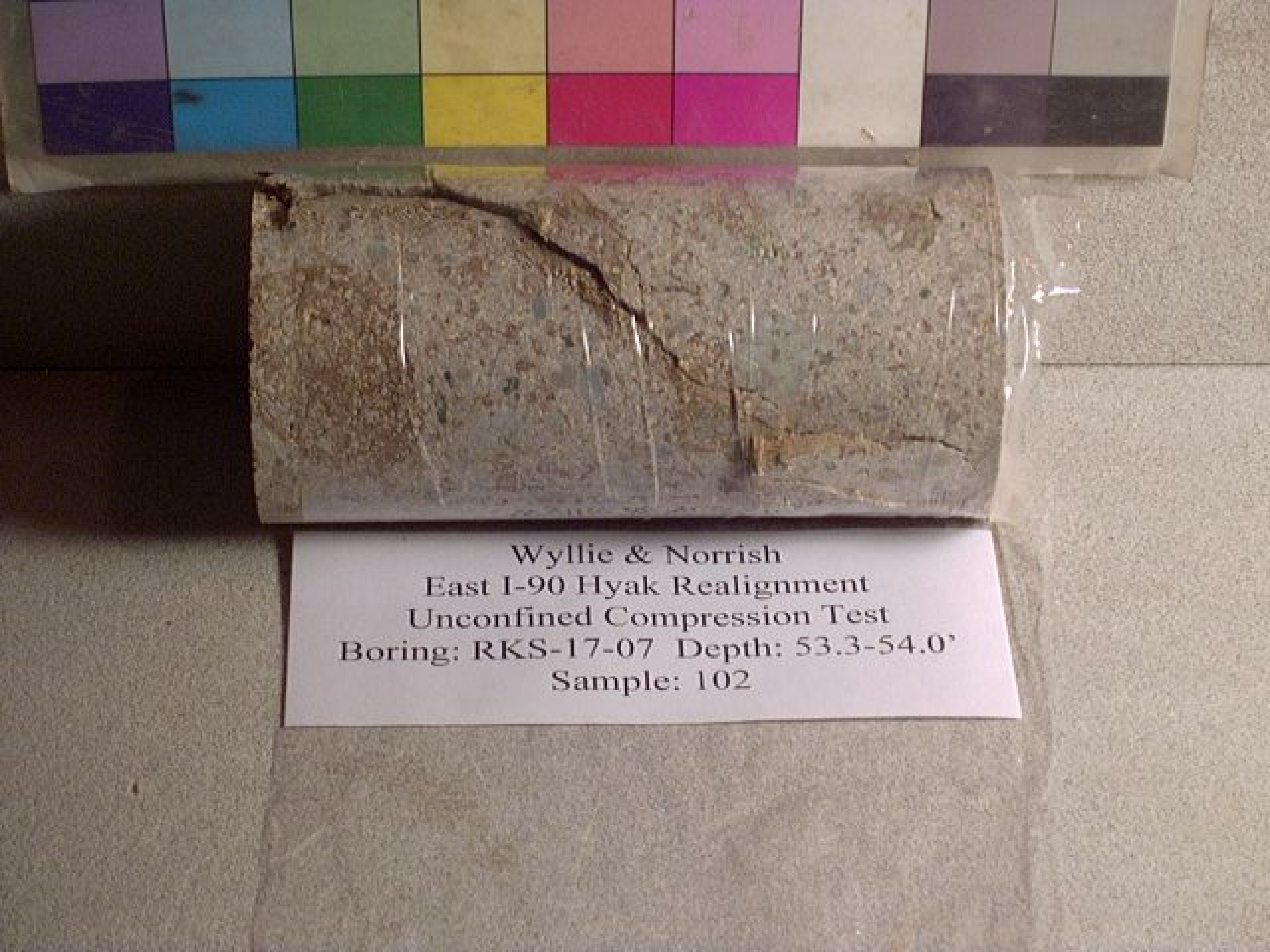

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-19-07 Depth: 30.4-31.4’
Sample: 102

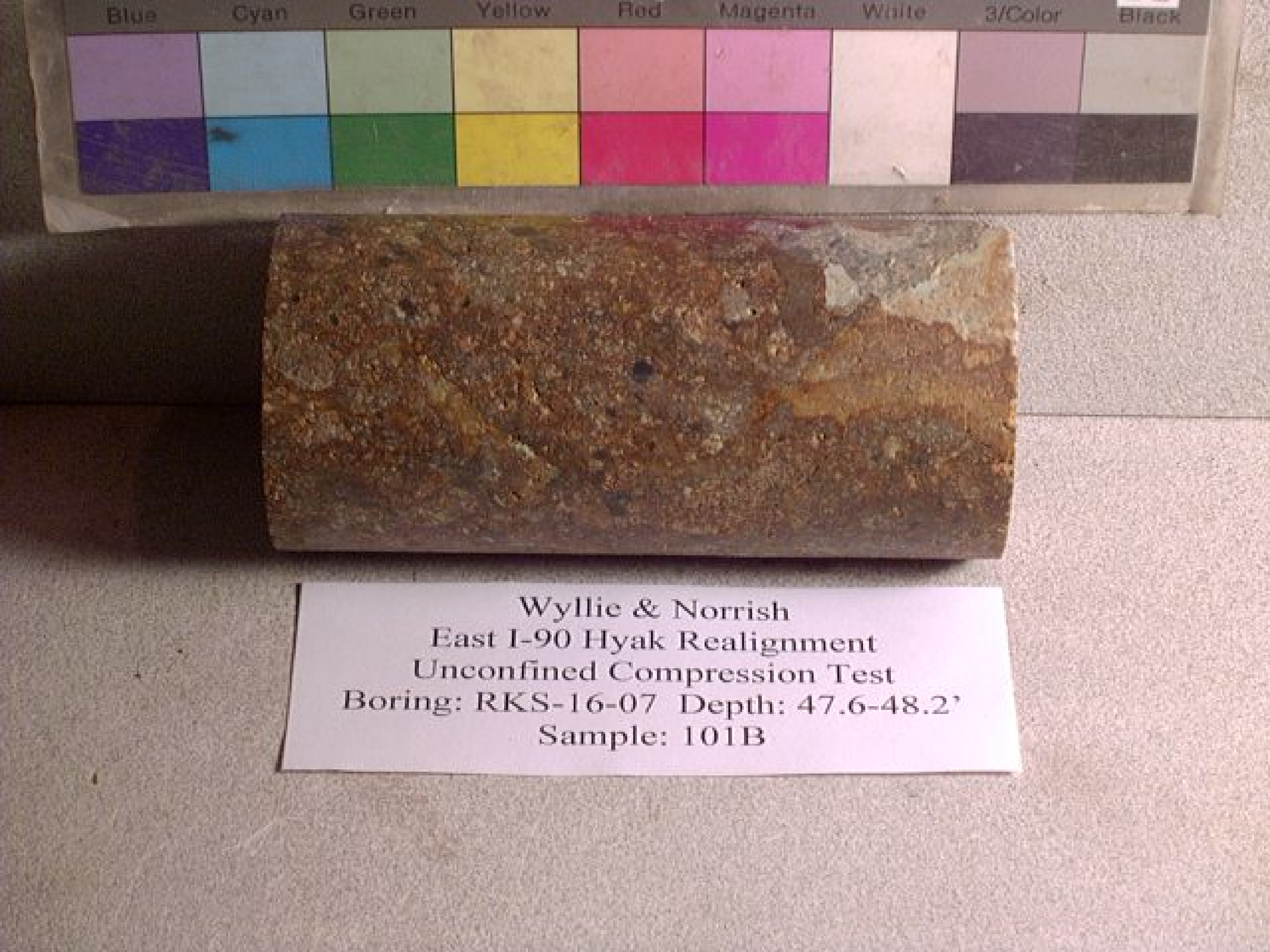

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-19-07 Depth: 30.4-31.4’
Sample: 102

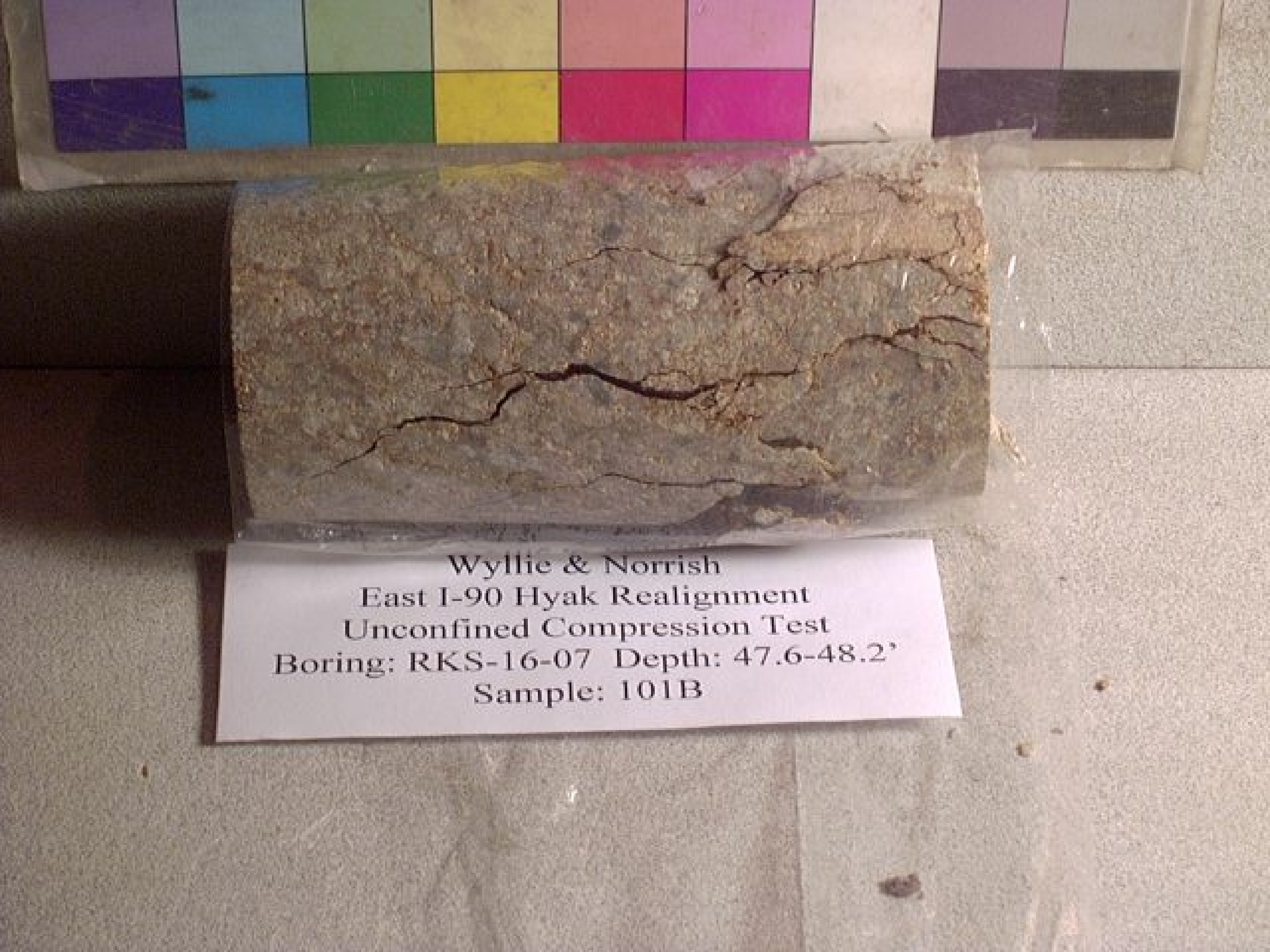

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-18-07 Depth: 72.5-72.9'
Sample: 102B

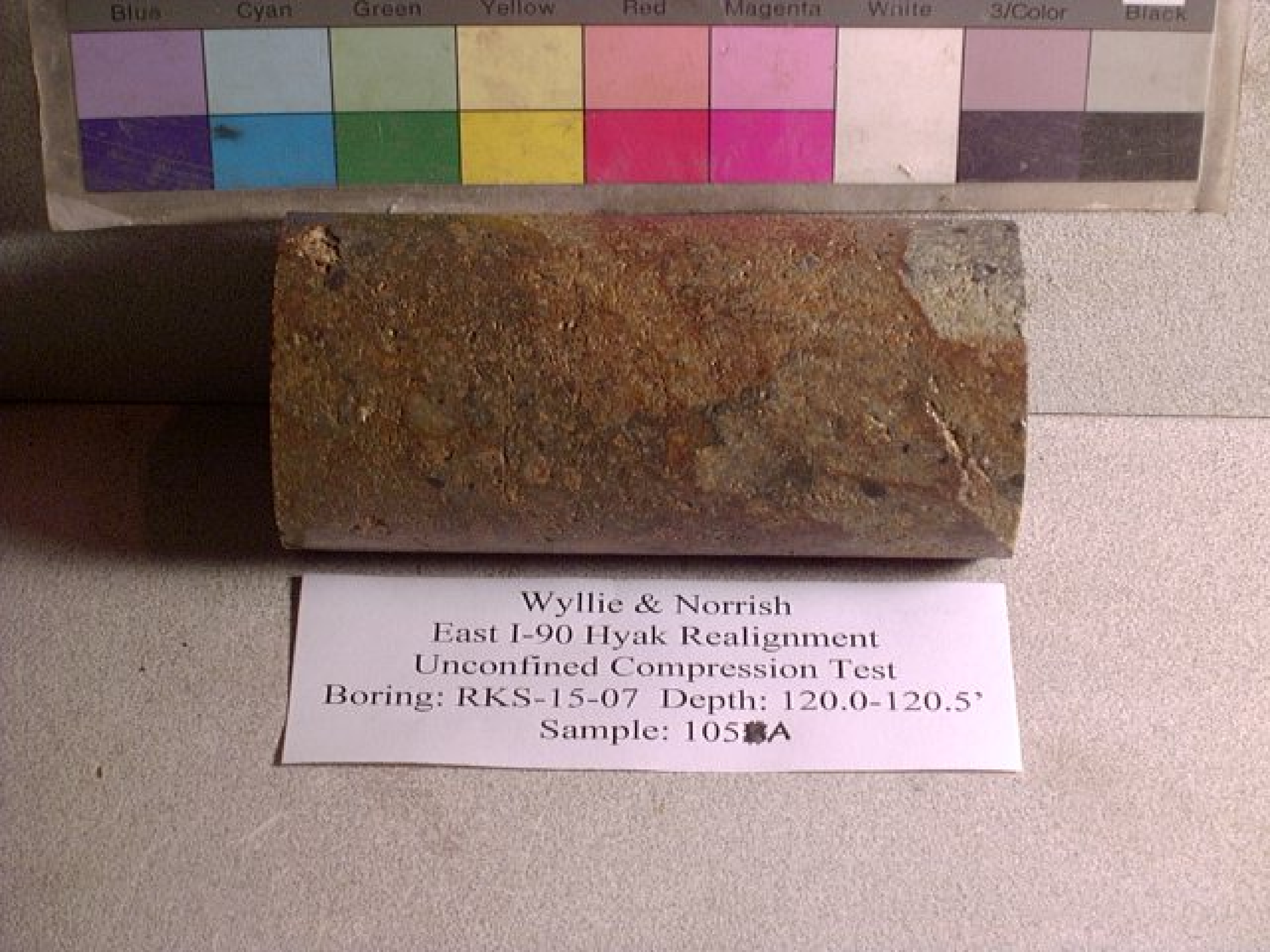

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-18-07 Depth: 72.5-72.9'
Sample: 102B


Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-17-07 Depth: 53.3-54.0'
Sample: 102

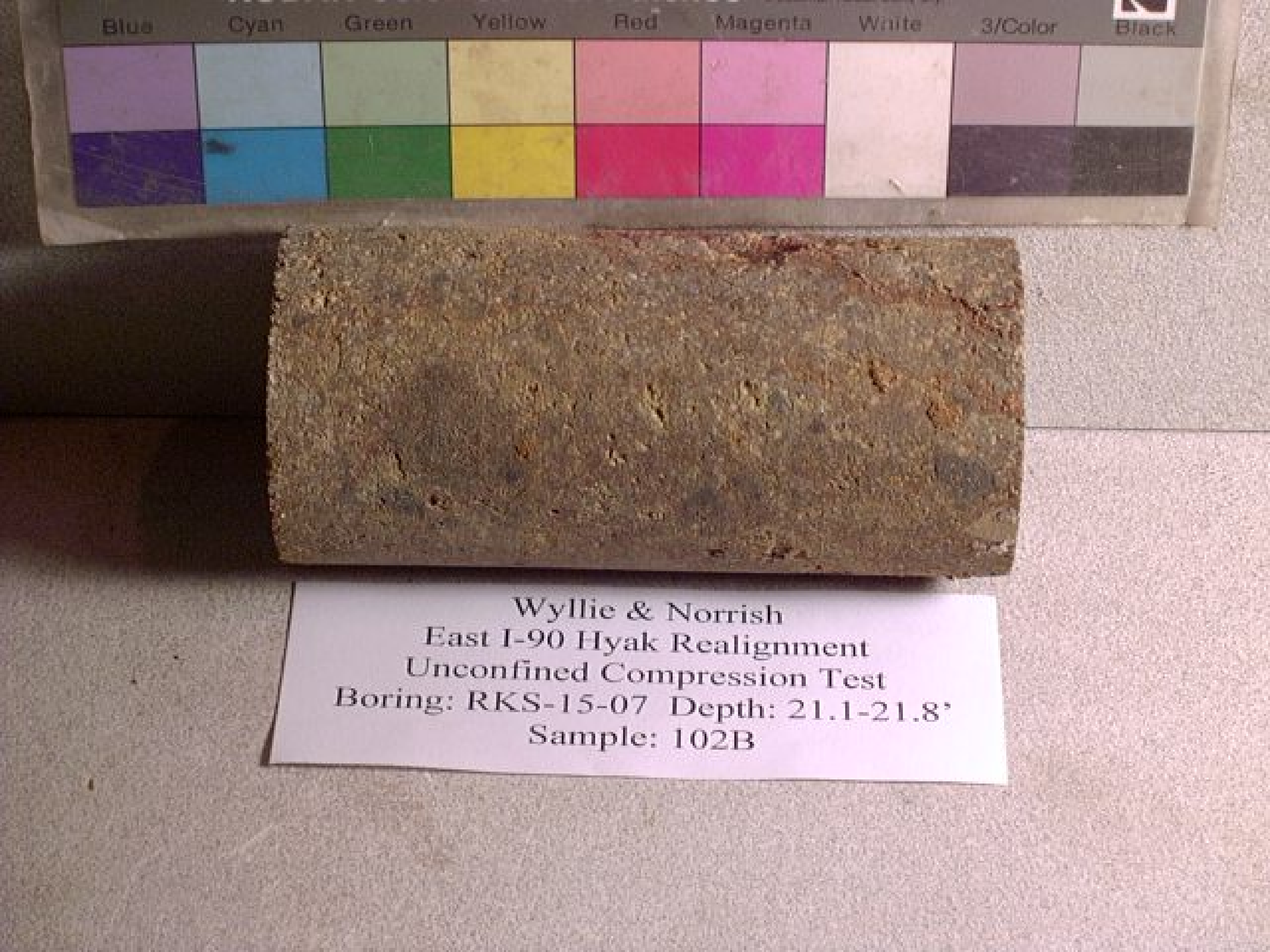

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-17-07 Depth: 53.3-54.0'
Sample: 102

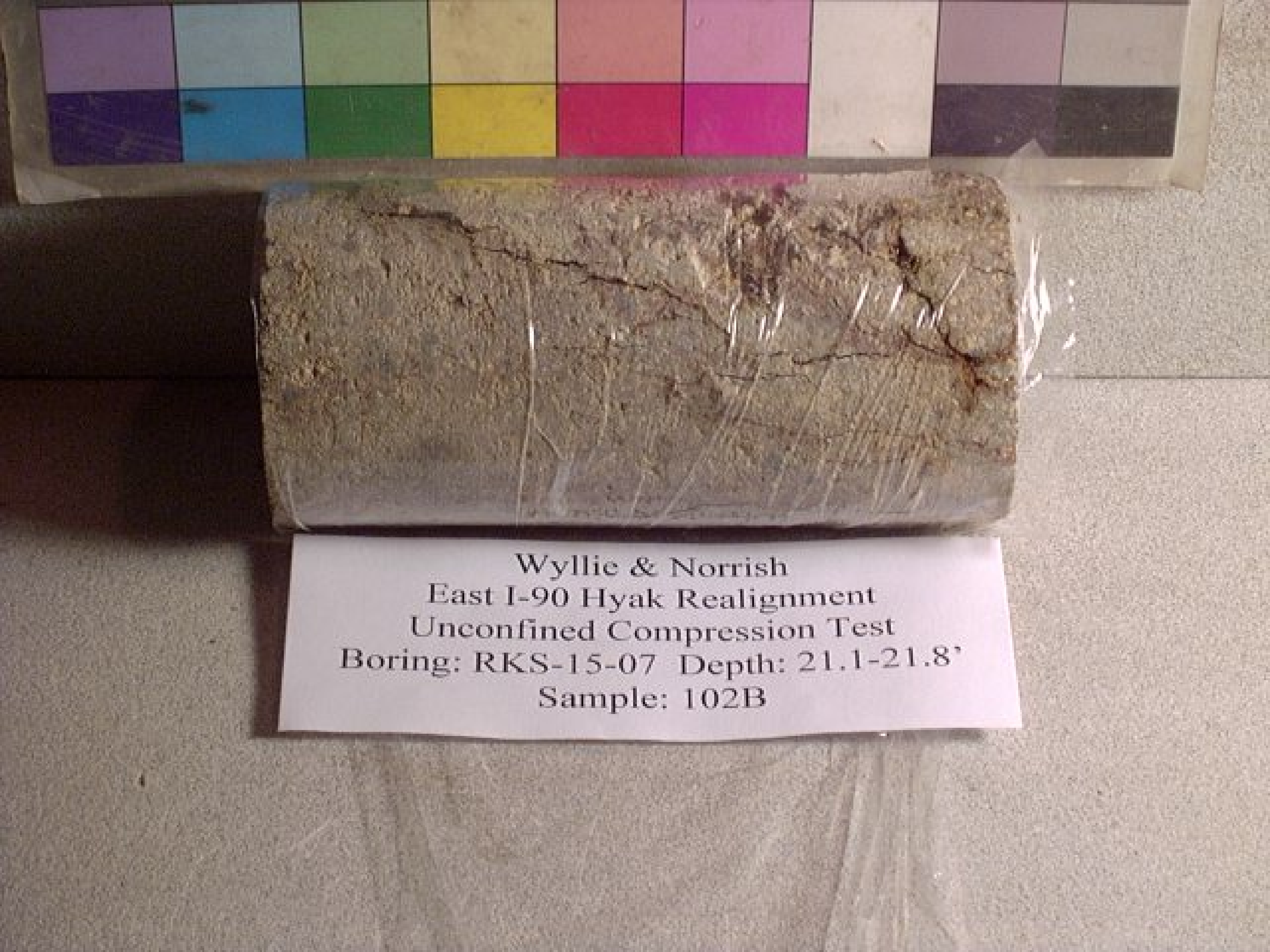

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-16-07 Depth: 47.6-48.2'
Sample: 101B

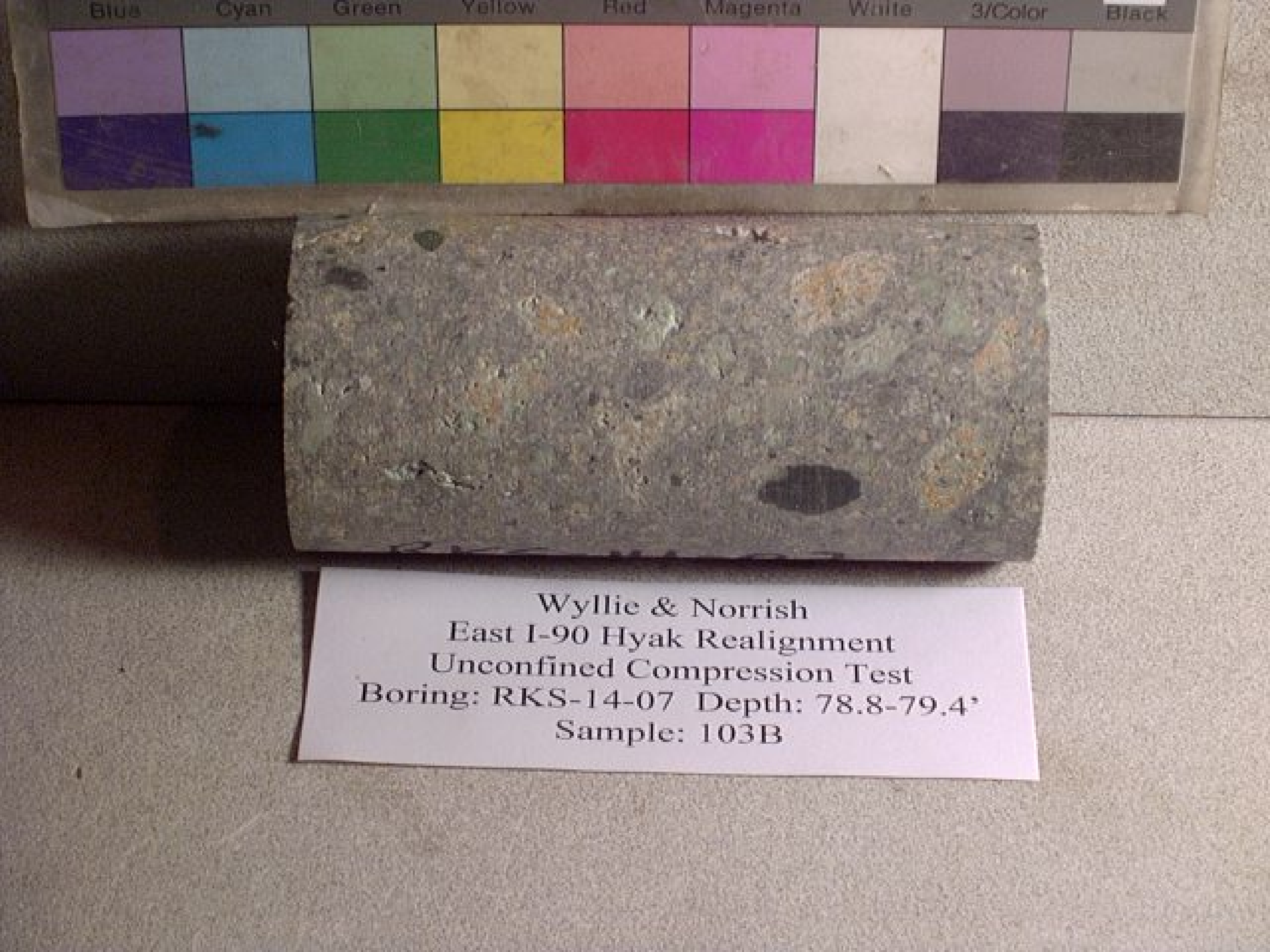

Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-16-07 Depth: 47.6-48.2'
Sample: 101B

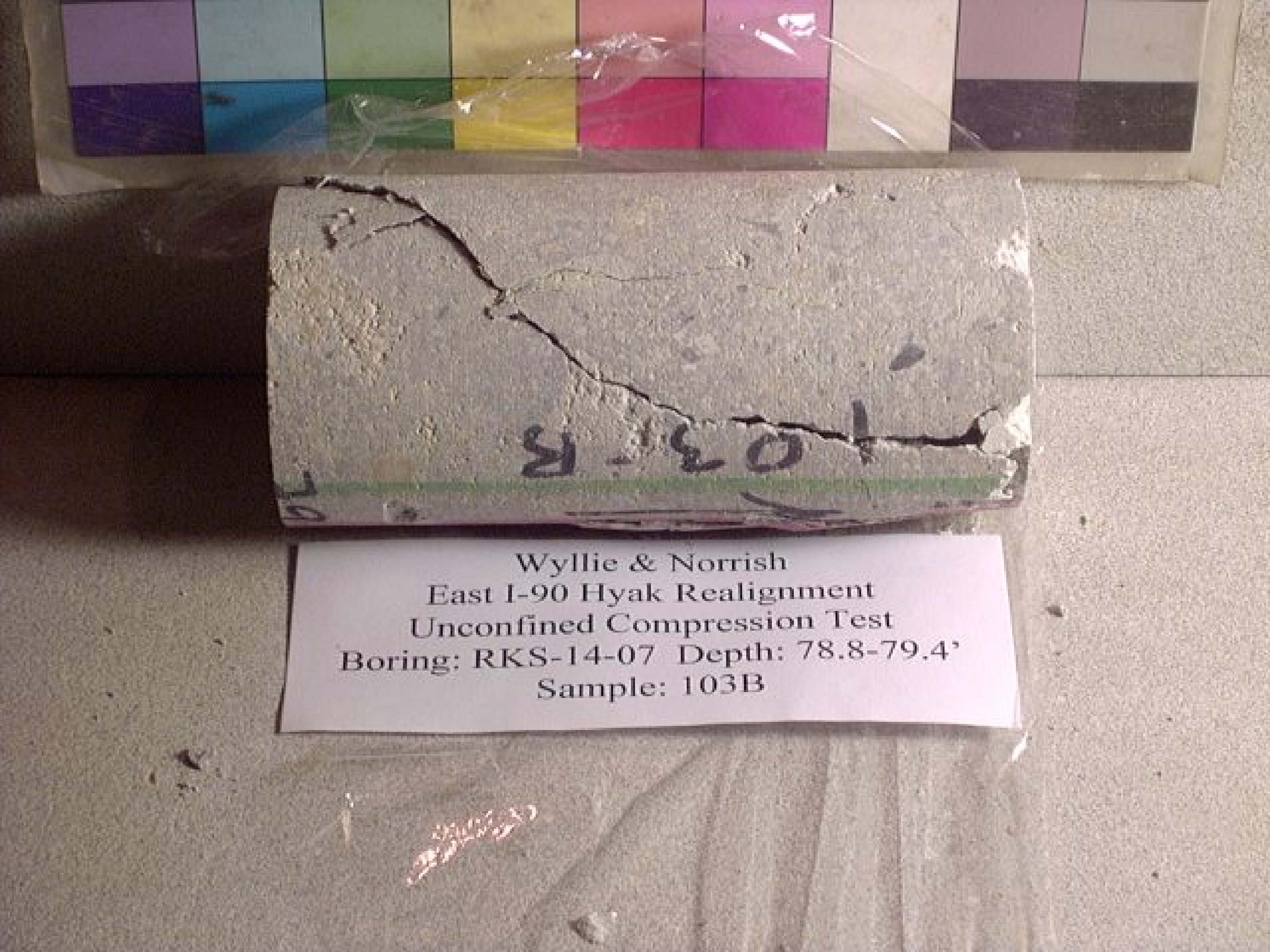

Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-15-07 Depth: 120.0-120.5'
Sample: 105[redacted]A

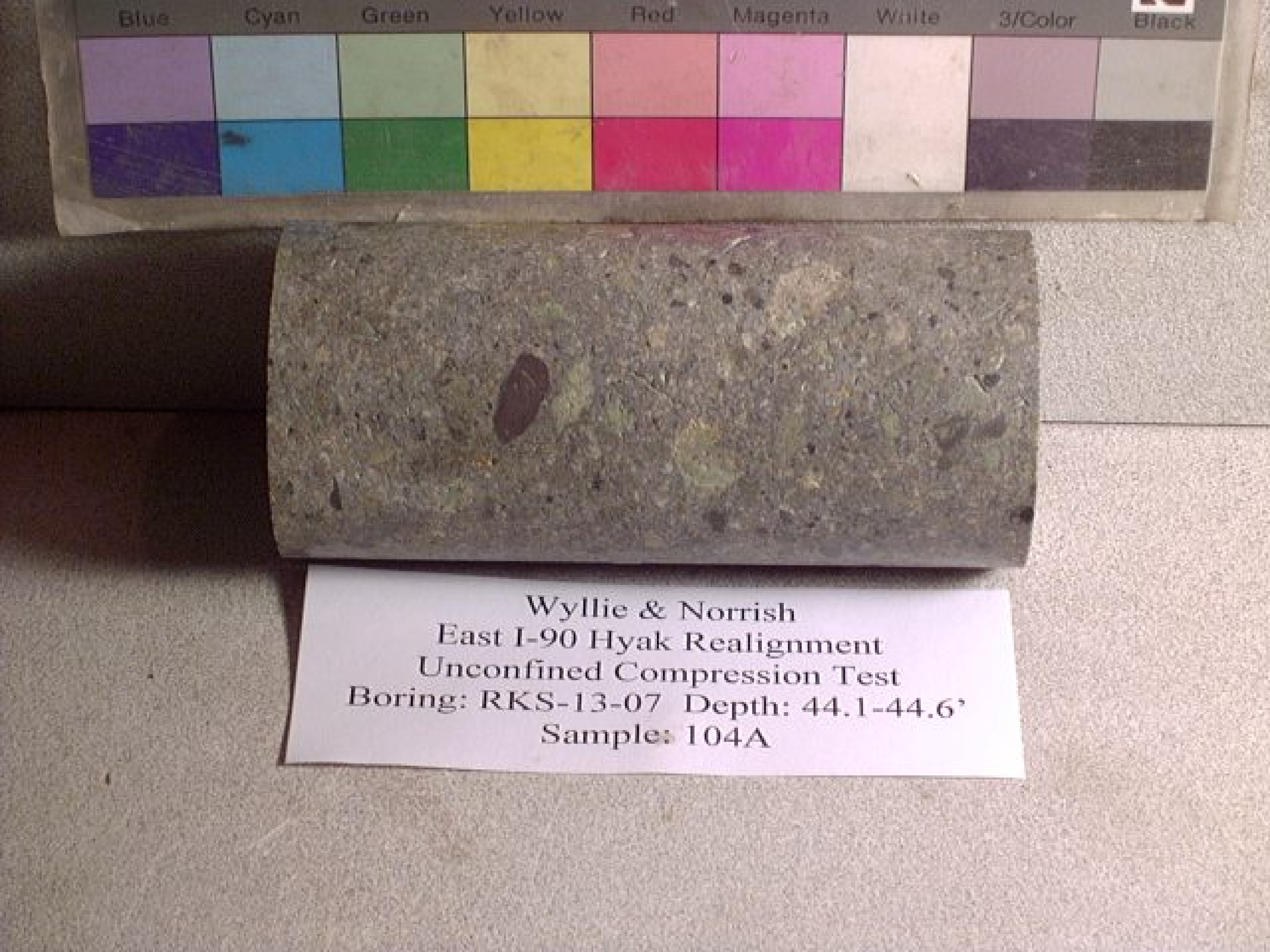

RKS-15-07
#105A
Wylie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-15-07 Depth: 120.0-120.5'
Sample: 105[redacted]A


Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-15-07 Depth: 21.1-21.8'
Sample: 102B


Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-15-07 Depth: 21.1-21.8’
Sample: 102B


Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-14-07 Depth: 78.8-79.4'
Sample: 103B


Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-14-07 Depth: 78.8-79.4'
Sample: 103B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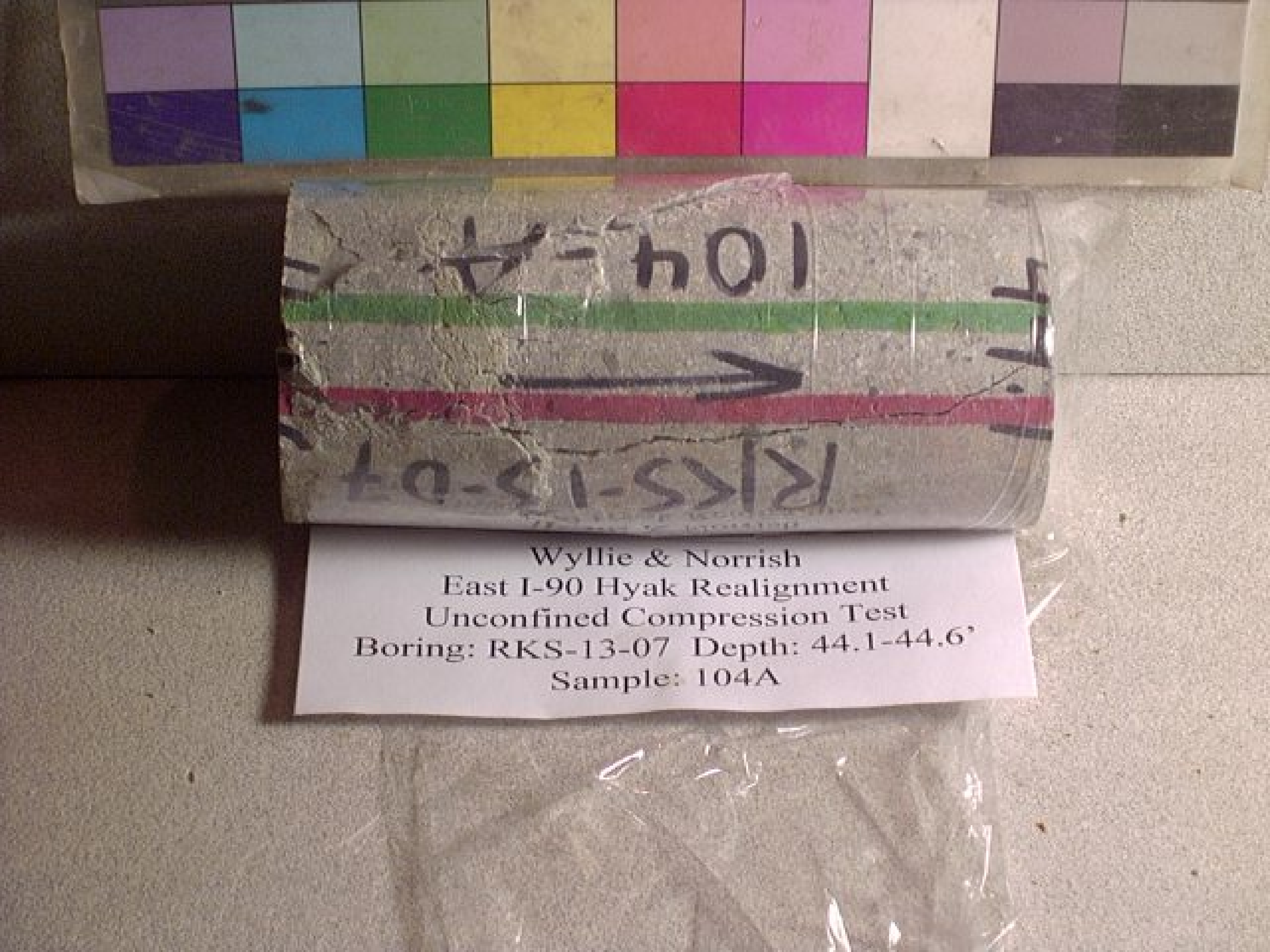
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-13-07 Depth: 44.1-44.6'
Sample: 104A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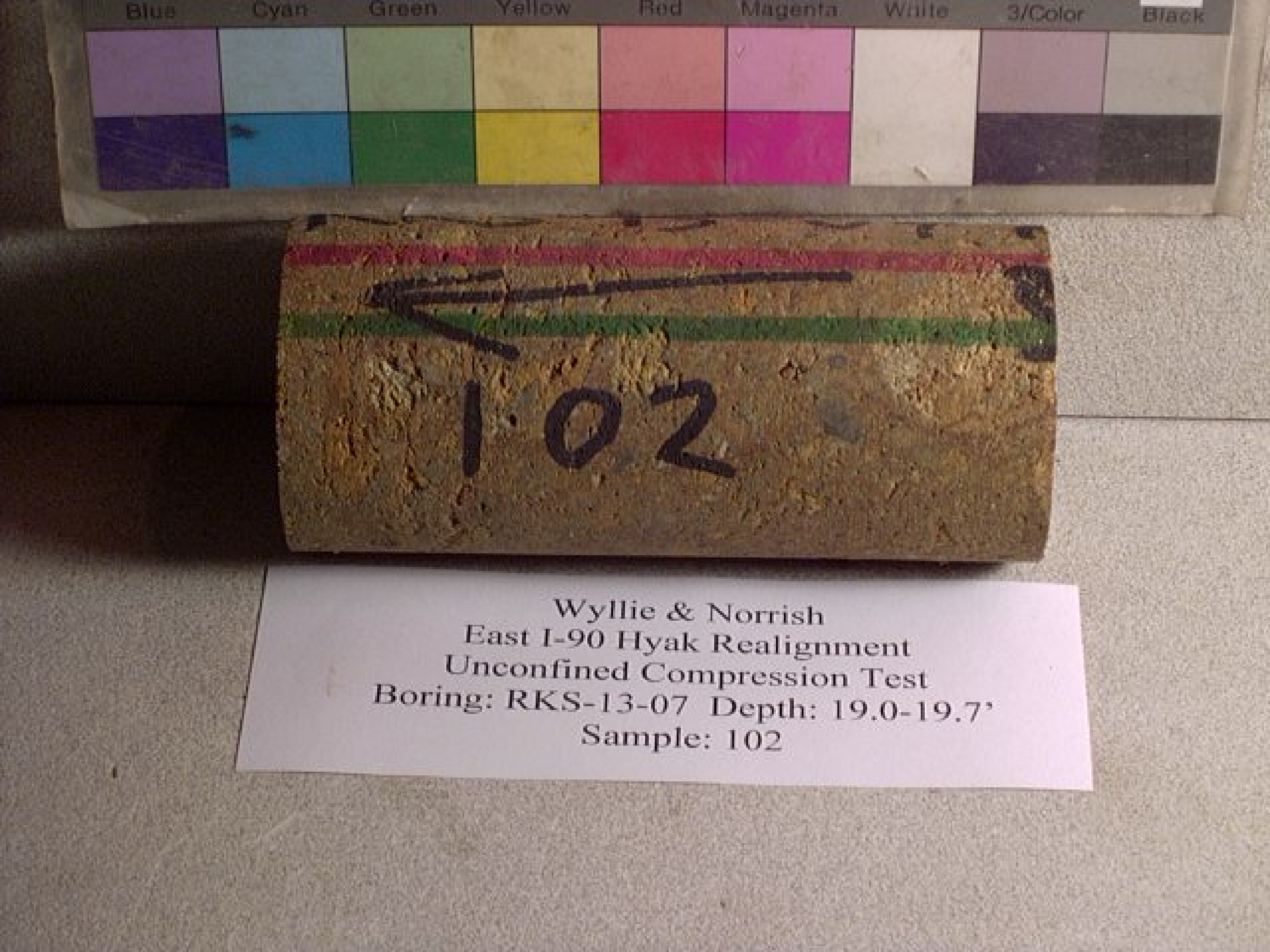
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-13-07 Depth: 44.1-44.6'
Sample: 104A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East I-90 Hyak Realignment
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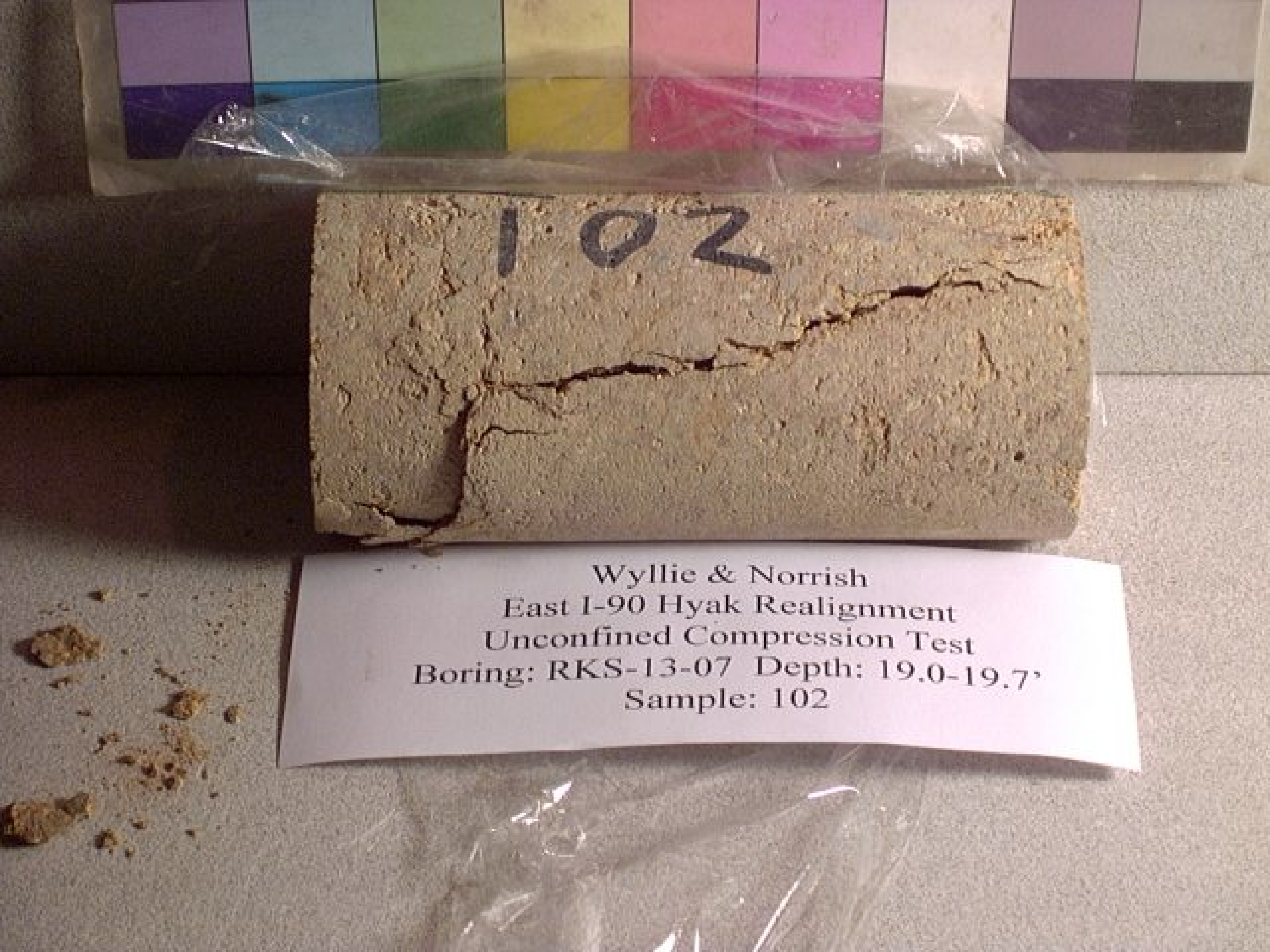
Boring: RKS-13-07 Depth: 19.0-19.7’
Sample: 102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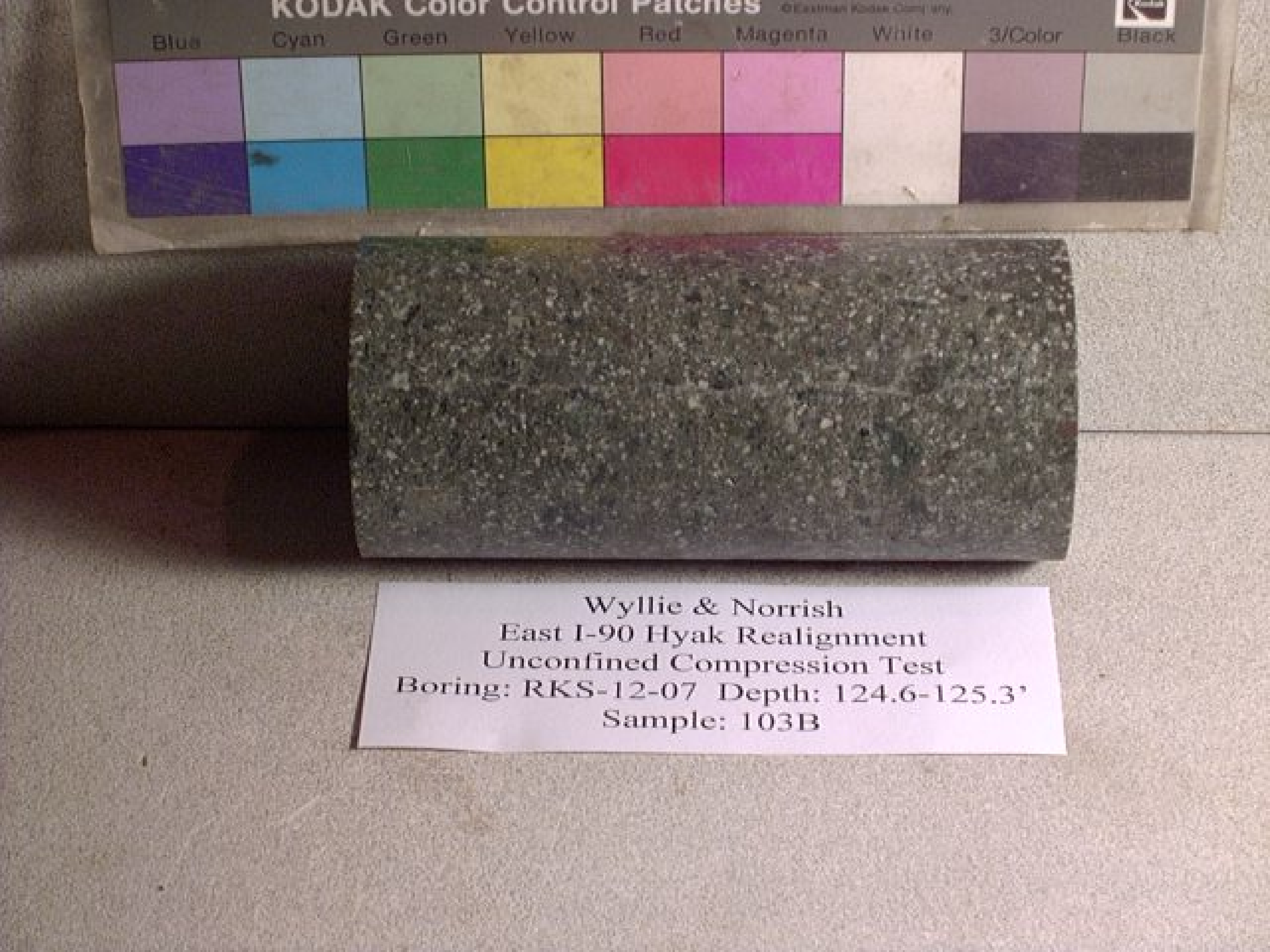
Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-13-07 Depth: 19.0-19.7'
Sample: 102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Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-12-07 Depth: 124.6-125.3'
Sample: 103B


KODAK Color Control Patches
Blue
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Magenta
White
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Wyllie & Norrish
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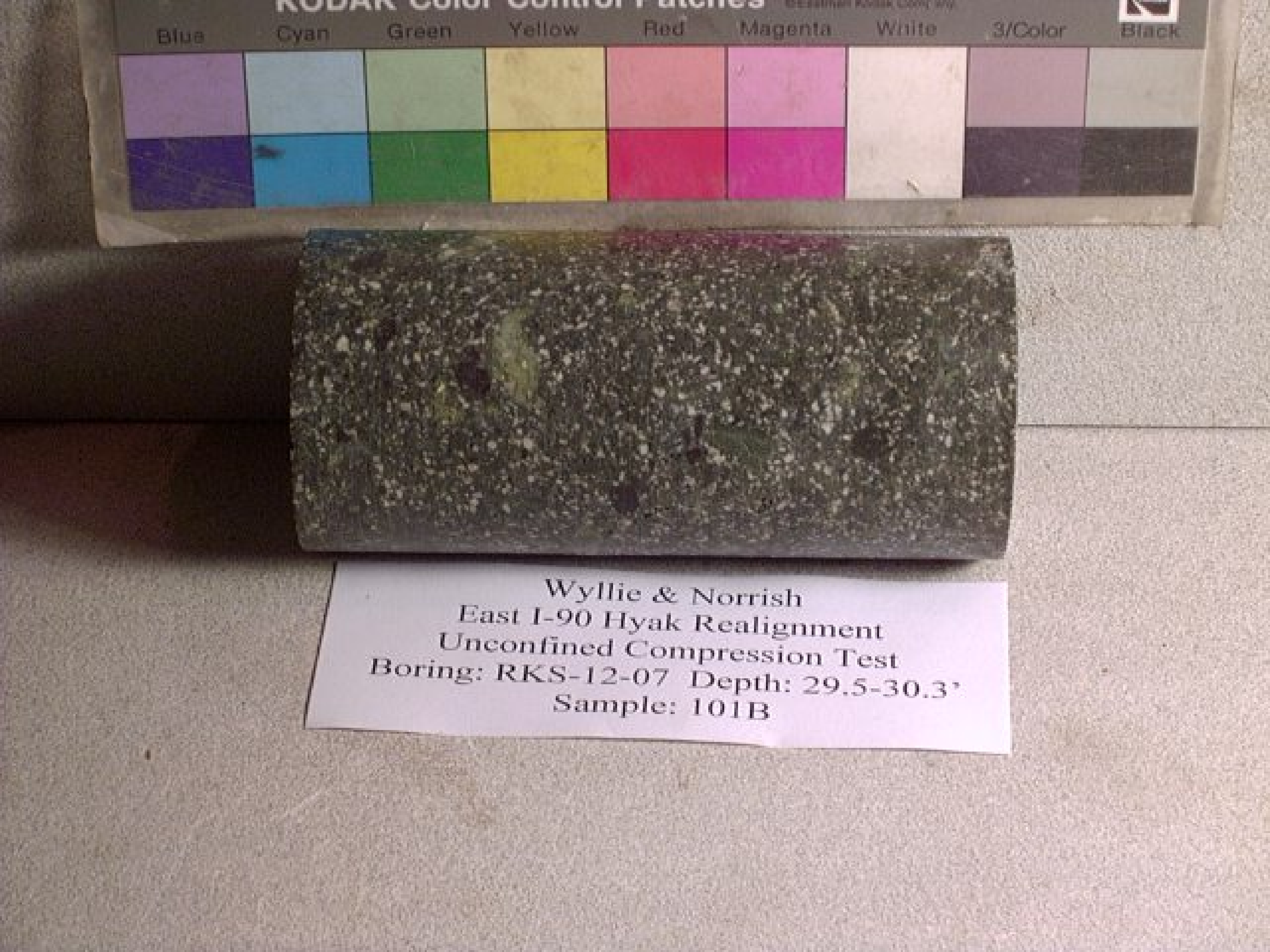
Unconfined Compression Test
Boring: RKS-12-07 Depth: 124.6-125.3'
Sample: 103B


KODAK Color Control Patches
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Wyllie & Norrish
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-12-07 Depth: 29.5-30.3'
Sample: 101B


KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
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Unconfined Compression Test
Boring: RKS-12-07 Depth: 29.5-30.3'
Sample: 101B

Geo Test Unlimited (GTU)

Test Equipment Design & Fabrication
Laboratory & Field Testing
Consulting Services

Dr. Anders Bro

November 22, 2008

Rock Testing
East I90 Hyak Extension

Wyllie & Norrish Rock Engineers
17918 NE 27th St.
Redmond, WA 98052

Dear Norm,

This letter report summarizes the unconfined compression, point load, and direct shear tests performed on the samples that you had sent to my lab a few weeks ago. The report summarizes the test results along with some comments about the testing program that you might find helpful in interpreting the results. The standard test procedures used for these tests are appended to this letter, along with a compact disk containing the data files and photographs of the pre-and post-test samples.

Of the all the samples sent to me, I tested 6 unconfined compression samples, 13 point load tests, and 4 direct shear tests. You had asked for axial and diametral point load tests to be performed, but often there was insufficient core to perform both of these tests.

Most of the samples consisted of meta-basalt, with a few sandstone and bedded quartzite samples. On looking at the samples identified at quartzite, I saw that the direct shear sample appeared to consist of quartzite clasts floating in a fine white matrix. This quartzite rock was interesting in that the samples appeared to be pervasively jointed with narrow zones on each side of the fractures been altered to a lighter gray color. These joints appeared to constitute planes of weakness, and were characterized by only moderate healing (some of which contained calcite).

A few of the unconfined compression samples with joints were “repaired” with cyanoacrylate glue. Sample 104A from Boring RKS-33-08 contained a joint that dipped at a shallow angle. This joint was still intact, but it was reinforced with glue so that it could be cut and ground without damaging the samples. The shallow dip of this joint made this a good candidate for “repair” in that any failure would pass diagonally across the glued joint and thus the glued joint would not be involved in the sample failure. On the other hand, Sample #102 from Boring RKS-46-08 was not a good candidate for joint gluing as this joint was so steeply inclined. The weak joint was intact, but it was clearly quite weak and wicked up the glue. In this case the sample failed along the pre-existing joint making this an invalid test. I had my doubts about the validity of gluing this sample, but I thought it would be interesting to verify my doubts, and so I performed the test. The strength would have been significantly lower had the joint not been glued.

The weaker samples were wrapped with heat shrink wrap prior to cutting and grinding to help reduce sample degradation during the preparation process.

Two of the direct shear samples consisted of saw-cut interfaces. An additional sample consisted of a clay/rock interface, and the last sample consisted of an oxide discolored natural joint.

The tests were performed according to the appended test procedures.

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Unconfined Compression and Point Load Testing

The objective of this testing program was to perform a set of unconfined compression tests along with companion axial and diametral point load tests so that a reasonable correlation between the test values could be developed

Unconfined Compressive Strength and Point Load Test Results

Boring/ Sample #	Depth (ft.)	Description	Density (pcf)	Corrected Point Load (psi)	UC Strength (psi)
RKS-32-08 #101B	29.0-29.6	Medium gray silty fine grained sandstone with a few thin calcite healed joints.	168.7	226[a.] 162[d.]	7036
RKS-33-08 #104A	64.5-65.1	Dark greenish gray somewhat altered meta-basalt with calcite healed fractures. One cross joint was open and weak and was repaired with cyanoacrylate glue.	172.0	415 [a.]	6925
RKS-34-08 #S-2-A	61.3-62.0	Medium gray meta-basalt with dark brick-red layers and diagonal calcite healed hairline joints.	171.9	344 [a.2.]	22,684
RKS-36-08 #S-1-B	16.0-16.6'	Medium gray meta-basalt with a few calcite healed hairline joints.	172.2	1229 [a.] 884 [d.]	>45,073[3.]
RKS-46-08 #101	50.7-51.2	Medium gray meta-basalt.		1294 [a.] 1138 [d.]	
RKS-46-08 #102	51.2-52.0	Medium gray meta-basalt with a major weak diagonal joint about 25 degrees to the core axis that was glued with cyanoacrylate glue.	166.7	1629 [a.] 1024 [d.1.] 811 [i.2.]	6063[4.]
RKS-47-08 #102	35.8-36.7	Medium gray quartzite with light gray discoloration along numerous diagonal joints about 40 degrees to the core axis. The weak fractured end-corner was repaired with cyanoacrylate glue.	161.8	413 [a.] 286 [d.2.]	2528

Notes: a. Axial Point Loading
d. Diametral Point Loading
i. Irregular Lump Point Loading
1. Invalid – failure did not pass through both points of loading.
2. Failed along existing planes of weakness.
3. The applied axial load exceeded the capacity of the loading frame.
4. The sample failed by shear along the glued diagonal joint

As noted in the table, Sample S-1-B from Boring RKS-36-08 was so strong that I could not fail it with my 200 kip loading system.

Sample #102 from Boring RKS-46-08 contained a steeply inclined glued fracture. This sample failed by shear along this glued joint. The hope was that the glue would have strengthened the sample enough to induce failure through the intact rock, but the steepness of the joint precluded this mode of failure. Thus this strength represents neither the intact strength of the rock nor the strength of the unglued rock joint. The sample would have been significantly weaker had it not been glued. Perhaps just the weight of the loading platens may have been enough to have failed the unglued joint.

Direct Shear Testing

Two tests were performed on saw-cut and ground interfaces created from the intact rock. One test was performed on a natural joint and one test was performed on a stiff clay/rock interface. My past experience with clay filled joints is that the rock/clay interface is typically the weak link and sliding generally occurs along these interfaces. Shear generally does not develop within the clay filling. Based on this observation, the clay/rock interface samples was positioned so that the interface was at the midplane of the shear box.

The goal was to test the samples at normal stresses of 10, 20, and 40 psi. For the clay/rock interface sample, I opted to test the sample at 5, 10, 20 , and finally 40 psi. Often when testing clay filled joints, the clay is so soft that the clay can squeeze out of the interface, resulting in an unrealistic test. The low initial normal stress was used to reduce the amount of clay extrusion, thus producing at least a few test results before the sample was potentially ruined. As it turns out, the clay was stiff enough that it did not squeeze out, producing good results at all four stages.

The following table summarizes the direct shear test results:

Direct Shear Test Results

Boring/ Sample #	Depth (ft.)	Description	Shear Intercept (psi)	Friction Angle (deg.)
RKS-35-08 #S-2-A	43.3-44.0	Saw-cut interface in medium gray meta-basalt.	0.3[i] 1.3[f]	22.4[i] 30.1[f]
RKS-35-08 #S-3-A	50.4-51.5	Contact between stiff greenish gray slickensided clay and altered meta-basalt.	1.8[i] 3.3[f]	16.3[i] 13.6[f]
RKS-9-08 #101	10.5-11.0	Slightly rough curved dark brown oxide coated joint in meta-lapilli tuff.	3.2[i] 2.7[f]	32.1[i] 30.4[f]
RKS-47-08 #103	41.3-42.0	Saw-cut interface in light to medium gray quartzite.	na(-0.6)[i] 0.2[f]	29.4[i] 32.9[f]

Notes: i. Initial strength parameter
f. Final strength parameter
na. The shear intercept is negative and not applicable

As with previous testing programs, the saw-cut interface tests can result in negative shear intercepts as seen in Sample #103 from Boring RKS-47-08. Negative intercepts are clearly inapplicable and are likely due to the strengthening of the interface as it incurred a shear displacement, thus effectively rotating the initial shear envelope in a counterclockwise manner, driving the intercept in a more negative direction. I have often encountered such negative intercepts for saw-cut interfaces and think that it is appropriate to simply ignore them and assume a zero intercept.

The most interesting sample was the clay/rock interface sample (Sample #S-3-A from Boring RKS-35-08). It was good to see that the clay was stiff enough to be able to sustain the normal stresses without extruding excessively from the interface. Most rock samples that I have tested generally have resulted in quite linear failure envelopes. This sample resulted in a marked non-linear behavior in both the initial and final failure envelopes, particularly at the lower levels of normal stress. Before using the linear strength parameters presented in the table above, it might be appropriate to evaluate the level of stress for the analysis and use friction angles/shear intercepts that are more in keeping with the level of stress in the analysis rather than the linear approximation presented above. For high levels of stress it might be appropriate to use a lower friction angle and a higher shear intercept and for lower levels of stress, one might want to use a higher friction angle, but a lower shear intercept.

As with other saw-cut interface tests that demonstrate stick-slip behavior, the interfaces generally exhibited displacement hardening. On post-test inspection, the interfaces were polished as a result of the testing, to the extent that they readily reflected light. It appears that this more polished surface was more frictional than the slightly rougher ground interface. I am not sure whether the initial or final strength parameters would be more appropriate for characterizing the basic friction angle.

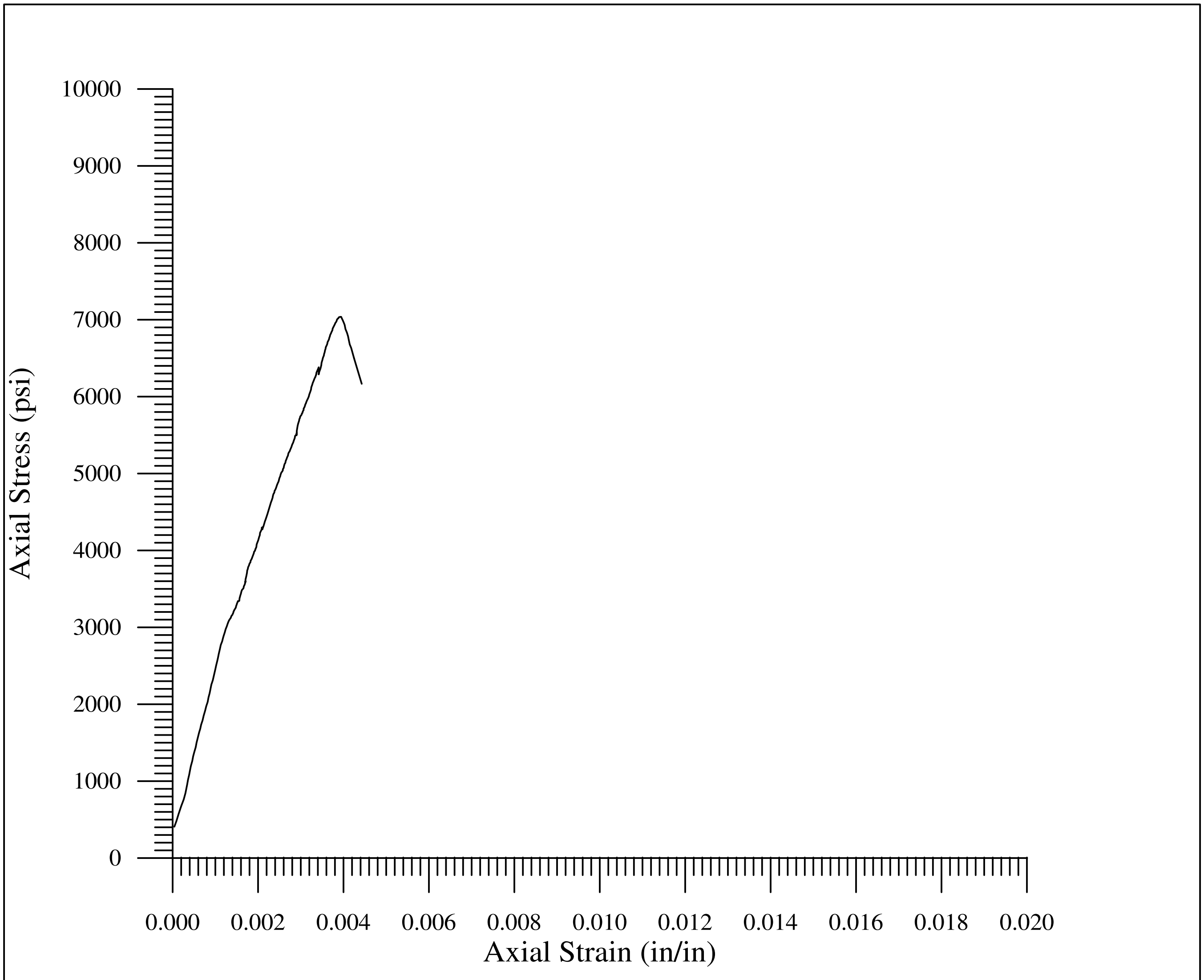
It should be noted that, as with all saw-cut and ground samples that I have tested, the interfaces exhibited a marked stick-slip behavior. The slip-action was accompanied by an audible "chunk" sound and was a decidedly dynamic event. As such, the stick-slip minima are a consequence of the dynamic overshoot of the slip event. The static friction angles are represented by the stick-slip peaks (used in this report to evaluate the failure envelopes) and the mid-points of the slip events likely represent the dynamic friction angles for this interface.

If you have any questions regarding these test results or the test procedures, please feel free to contact me so that we can discuss any of your concerns.

for GeoTest Unlimited

____

Dr. Anders Bro



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 101B
Boring: RKS-32-08
Depth: 29.0-29.6'

DESCRIPTION

Medium gray silty fine grained sandstone with a few thin calcite healed joints.

Density: 168.7 pcf
Strength: 7036 psi

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Nevada City, CA 95959

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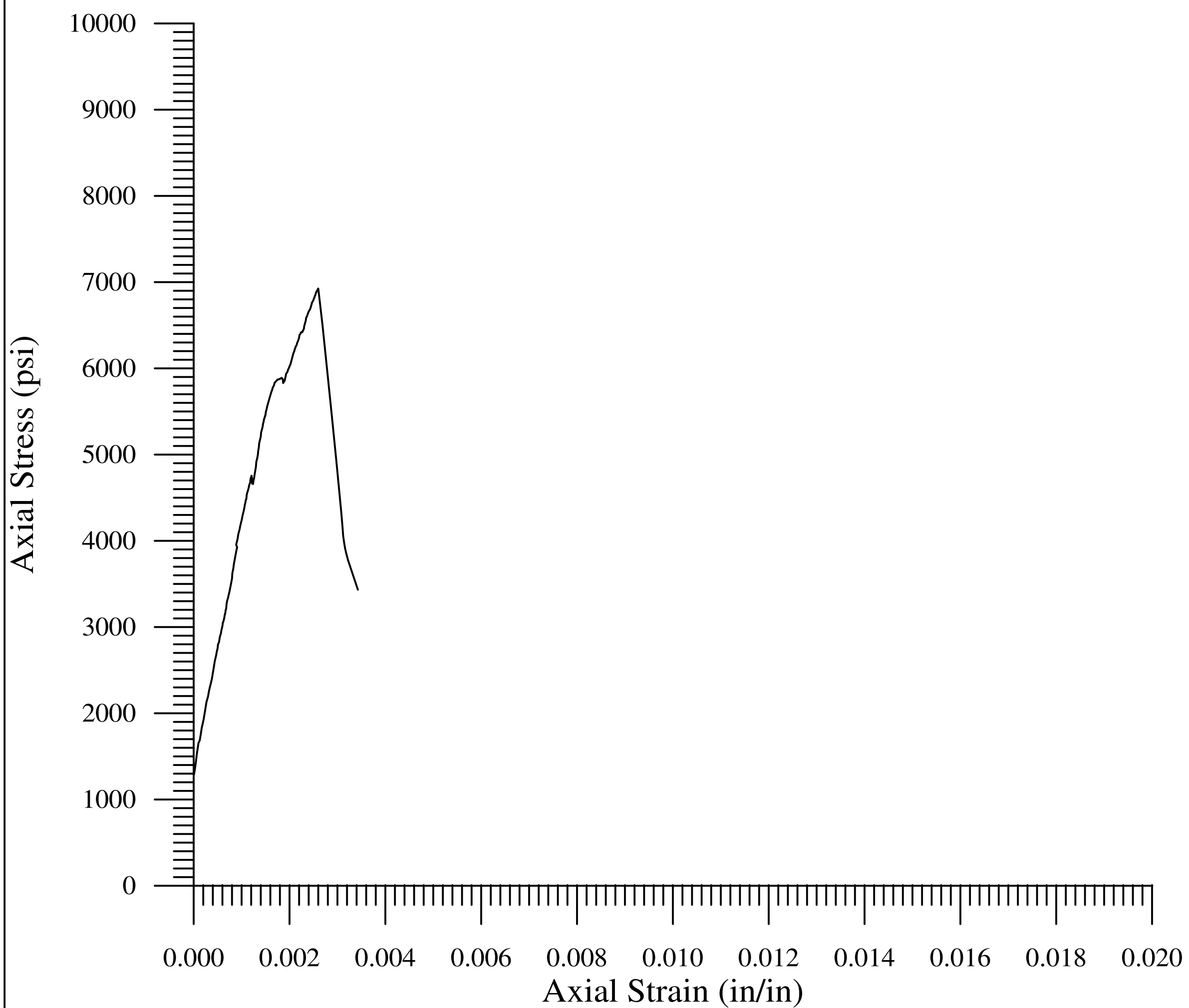
Redmond, WA 98052

Project: East I-90 Hyak Realignment

Project Number: 103WA

Test Date: November 19, 2008



UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 104A
Boring: RKS-33-08
Depth: 64.5-65.1'

DESCRIPTION

Dark greenish gray somewhat altered meta-basalt with clacite filled fractures. One cross joint was open and weak and "repaired" with cyanoacrylate glue. Failure did not involve the glued joint.

Density: 172.0 pcf
Strength: 6925 psi

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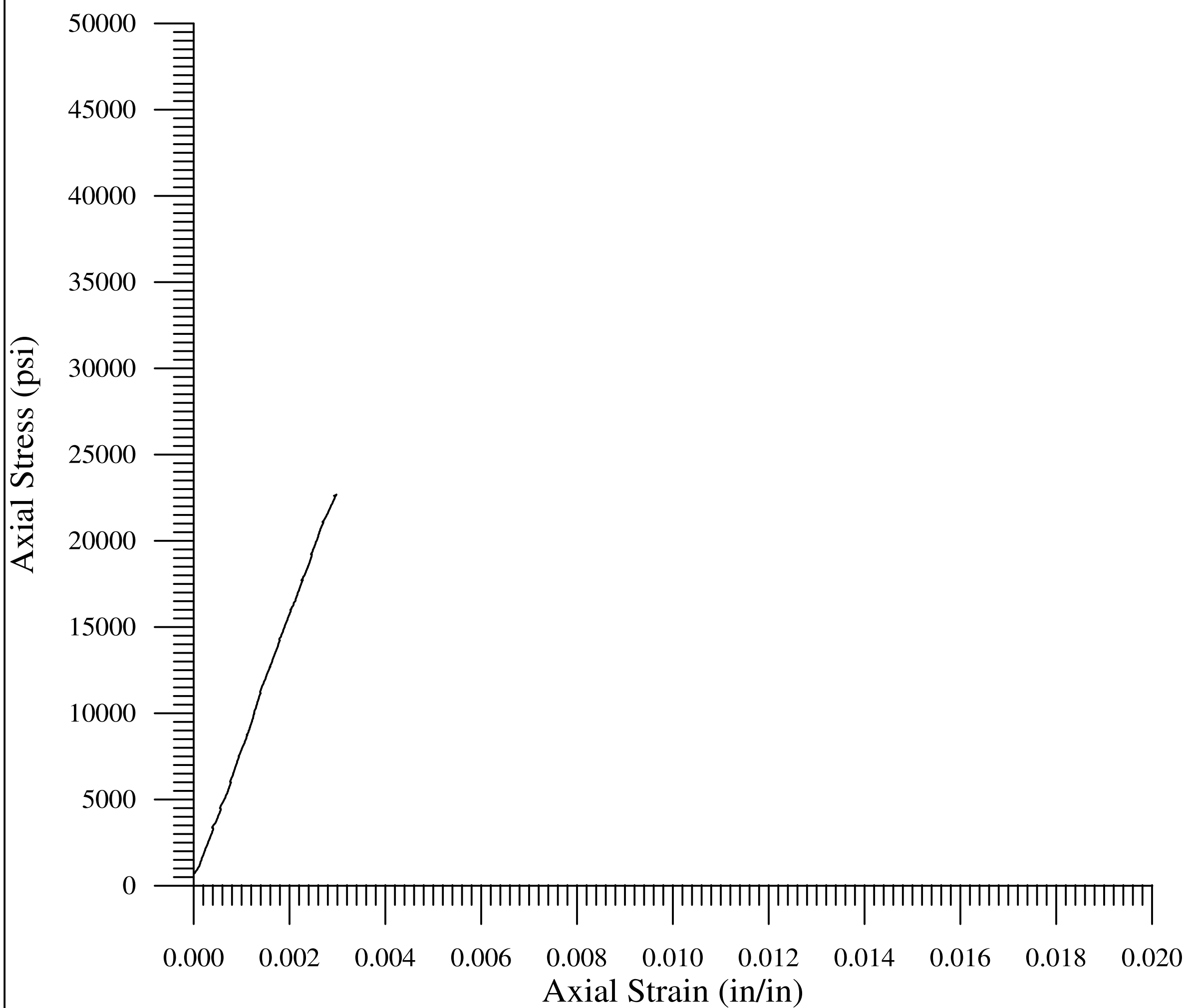

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: S-2-A
Boring: RKS-34-08
Depth: 61.3-62.0'

DESCRIPTION

Medium gray meta-basalt with dark brick-red layers and diagonal calcite healed hairline joints.

Density: 171.9 pcf
Strength: 22,684 psi

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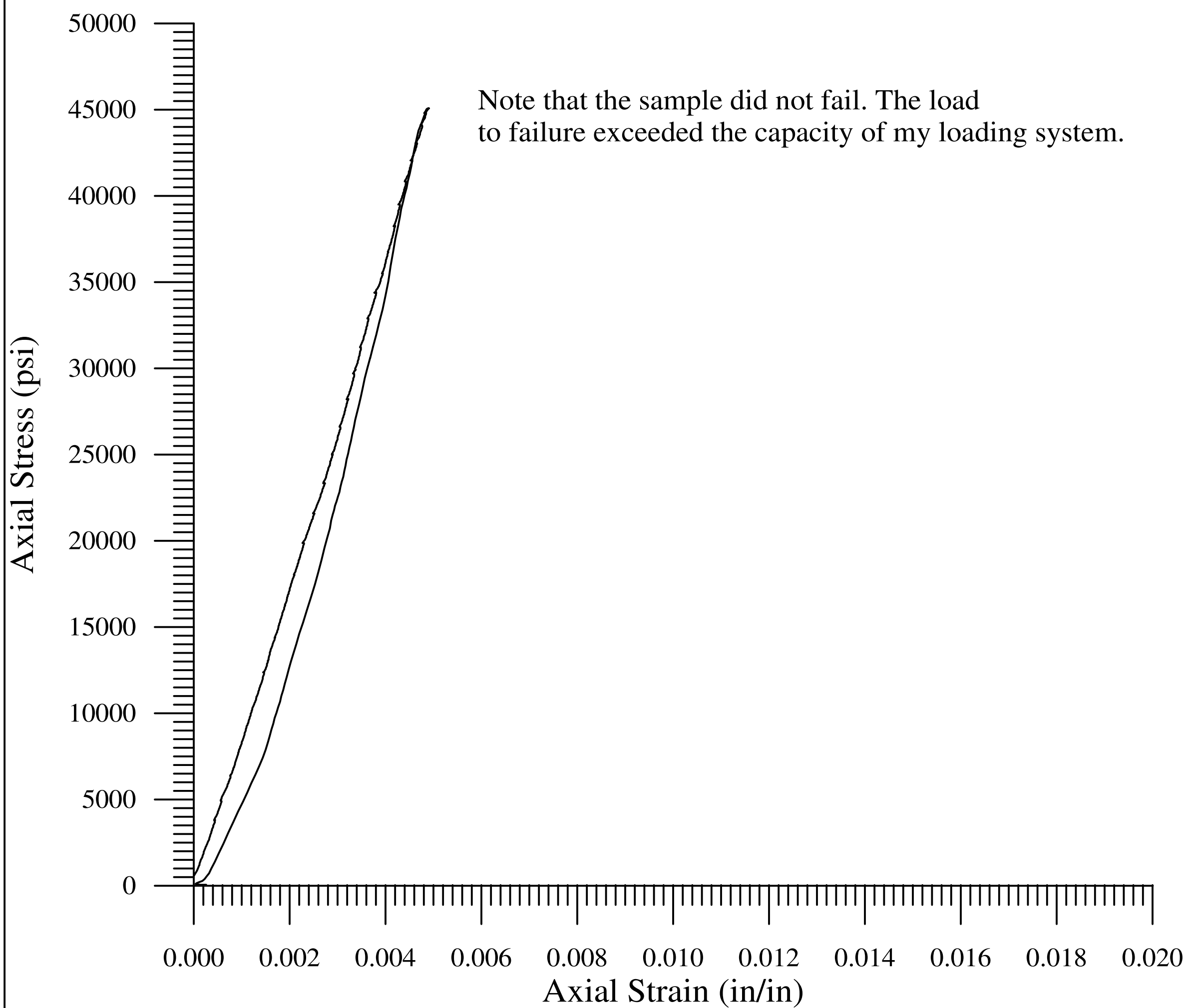

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: S-1-B
Boring: RKS-36-08
Depth: 16.0-16.6'

DESCRIPTION

Medium gray meta-basalt with a few calcite healed hairline joints.

Density: 172.2 pcf
Strength: >45,073 psi

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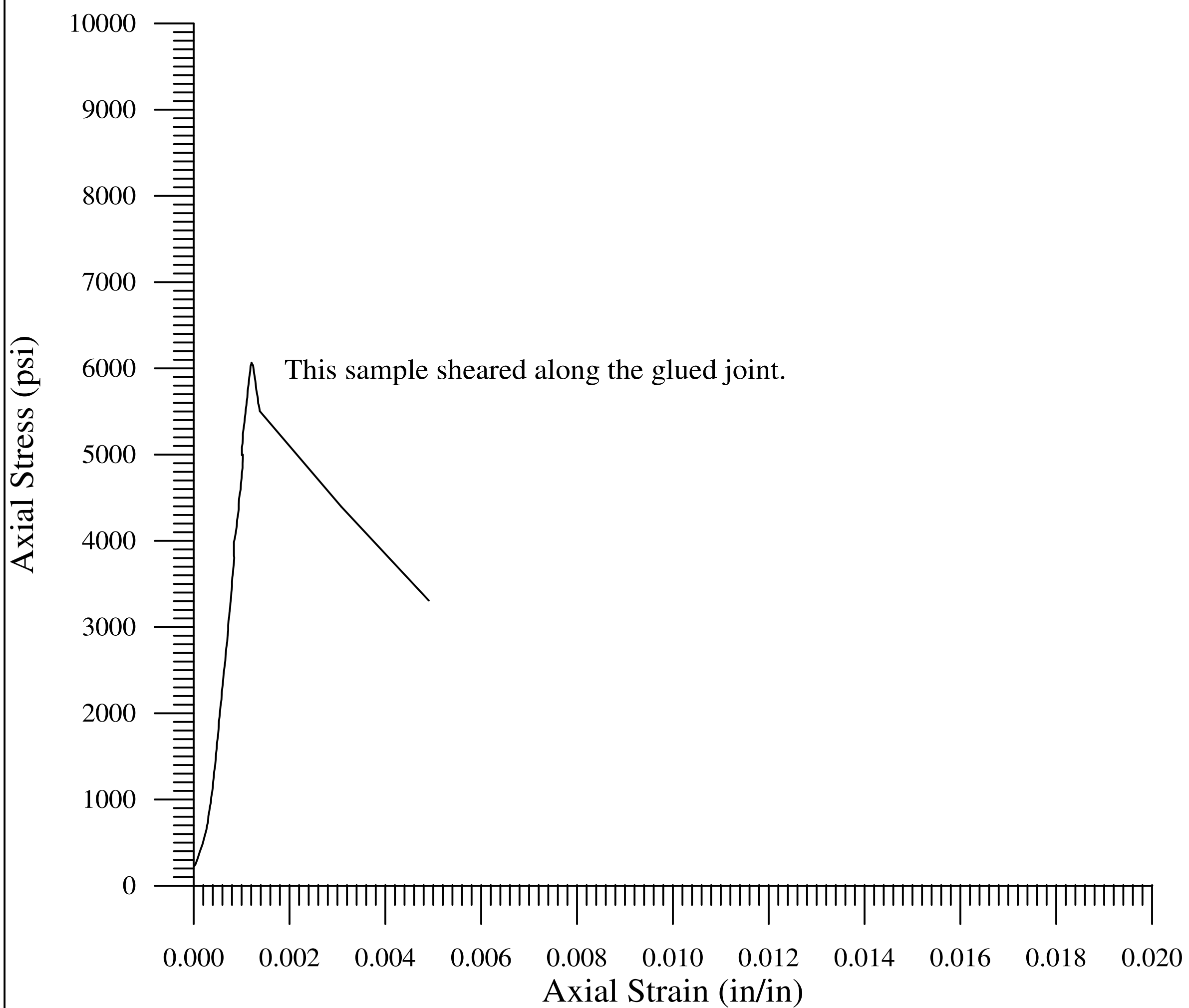

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102
Boring: RKS-46-08
Depth: 51.2-52.0'

DESCRIPTION

Medium gray meta-basalt with a major weak diagonal joint about 25 degrees to the core axis that was glued with cyanoacrylate glue.

Density: 166.7 pcf
Strength: 6063 psi

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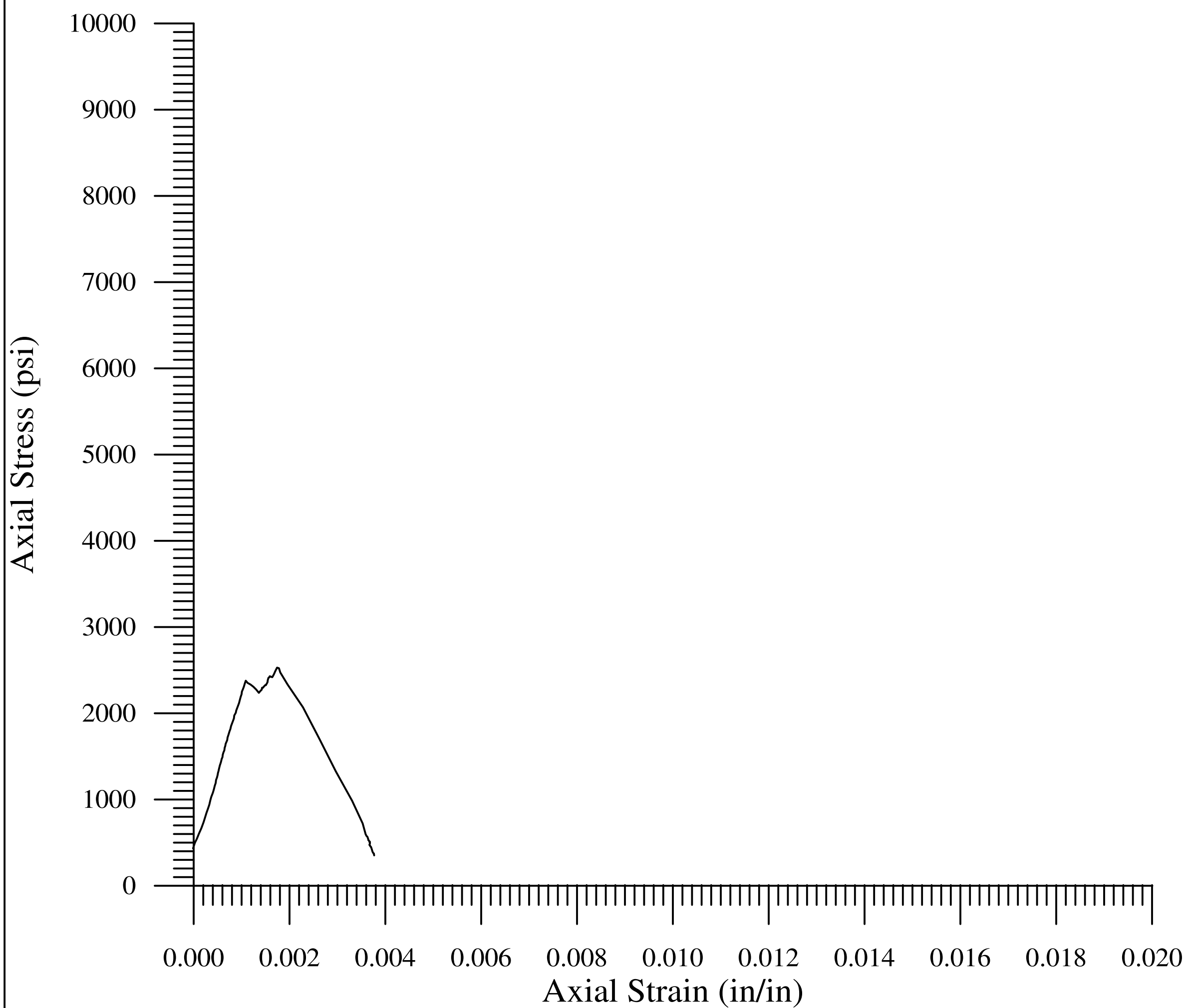

UNCONFINED COMPRESSION TEST
Axial Stress vs. Strain

Sample: 102
Boring: RKS-47-08
Depth: 35.8-36.7'

DESCRIPTION

Medium gray quartzite with light gray discoloration along numerous diagonal joints about 40 degrees to the core axis. The end fractures are repaired with cyanoacrylate glue.

Density: 161.8 pcf
Strength: 2528 psi

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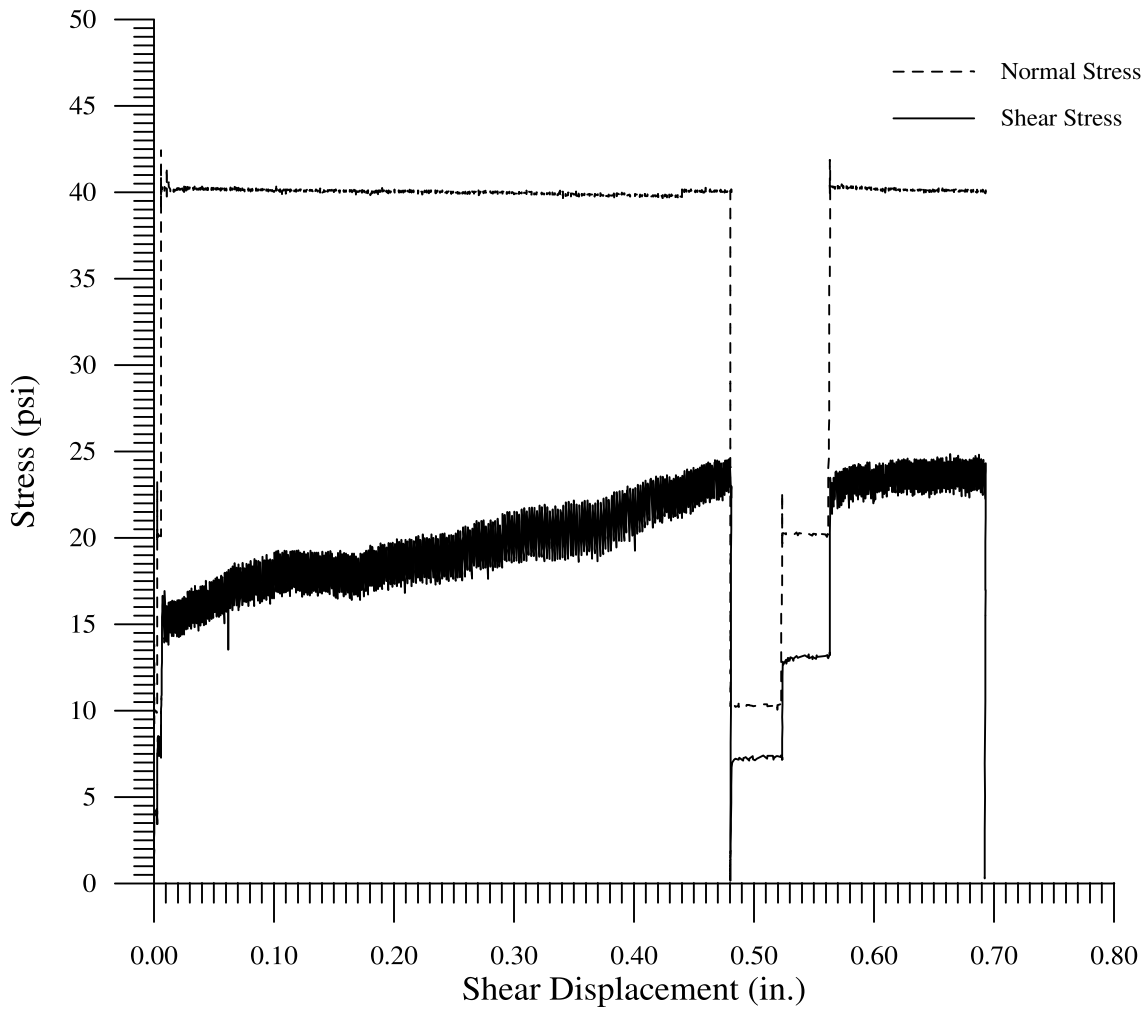

DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: S-2-A
Boring: RKS-35-08
Depth: 43.3-44.0'

DESCRIPTION

Saw-cut interface in medium gray meta-basalt.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.0	4.4
	20.1	8.5
	40.1	16.8
Final	10.1	7.2
	20.1	13.0
	39.9	24.5

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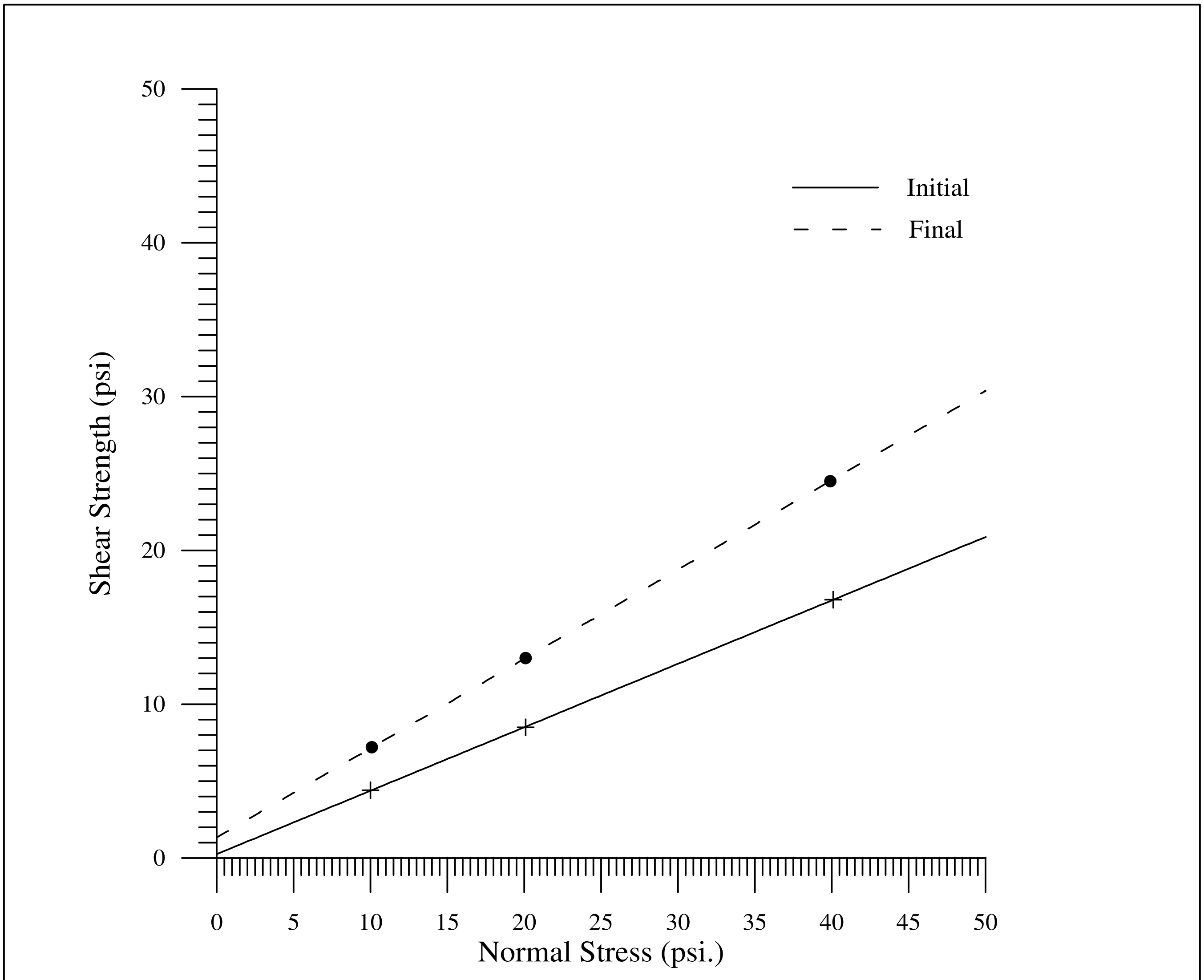

DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: S-2-A
Boring: RKS-35-08
Depth: 43.3-44.0'

DESCRIPTION

Saw-cut interface in medium gray meta-basalt.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	0.3	22.4
Final	1.3	30.1

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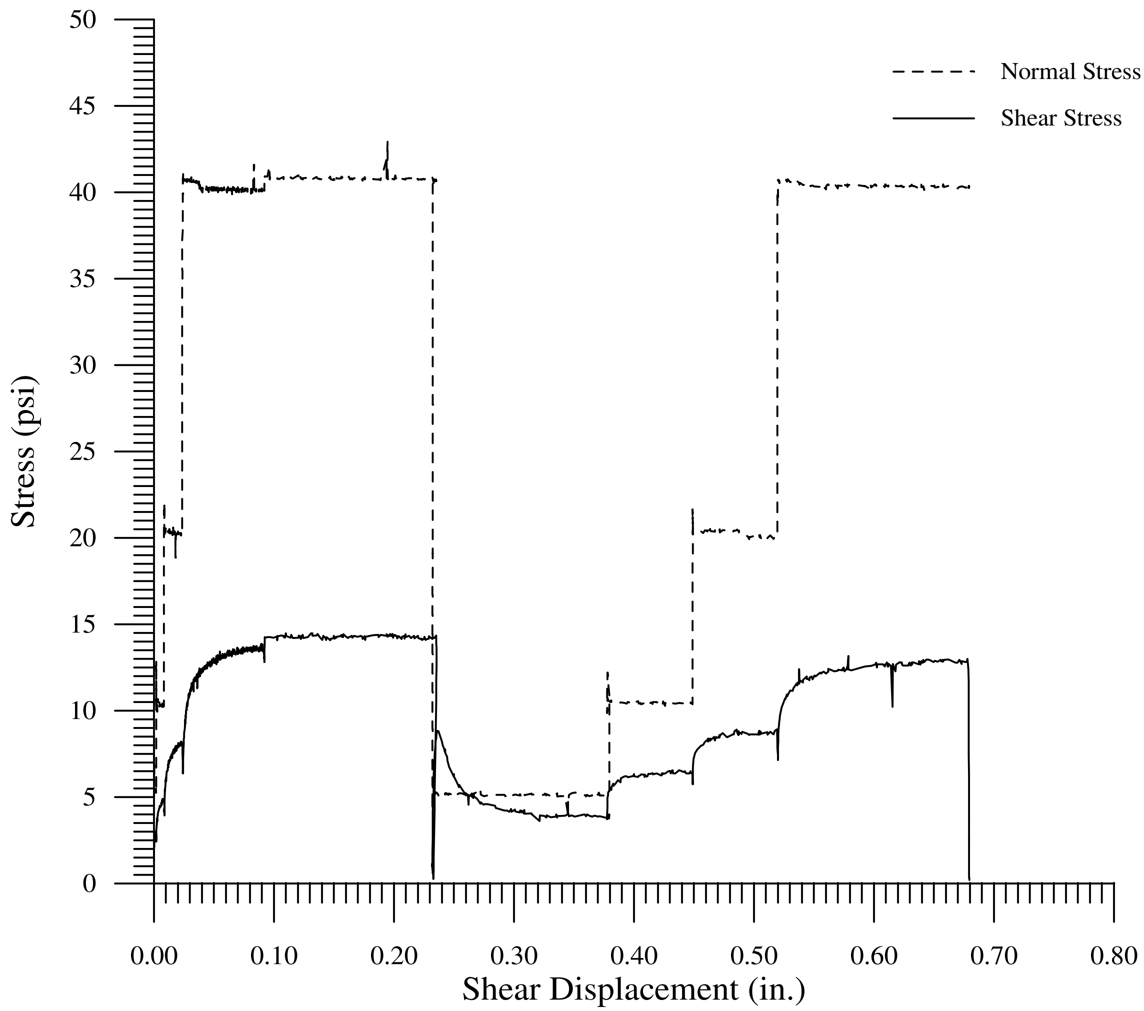

DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: S-3-A
Boring: RKS-35-08
Depth: 50.4-51.5'

DESCRIPTION

Contact between stiff greenish gray slickensided clay and altered meta-basalt.

	Normal Stress (psi)	Shear Strength (psi)
Initial	5.5	3.0
	10.4	5.0
	20.2	8.6
	40.1	13.3
Final	5.0	3.8
	10.3	6.4
	20.0	8.7
	40.2	12.8

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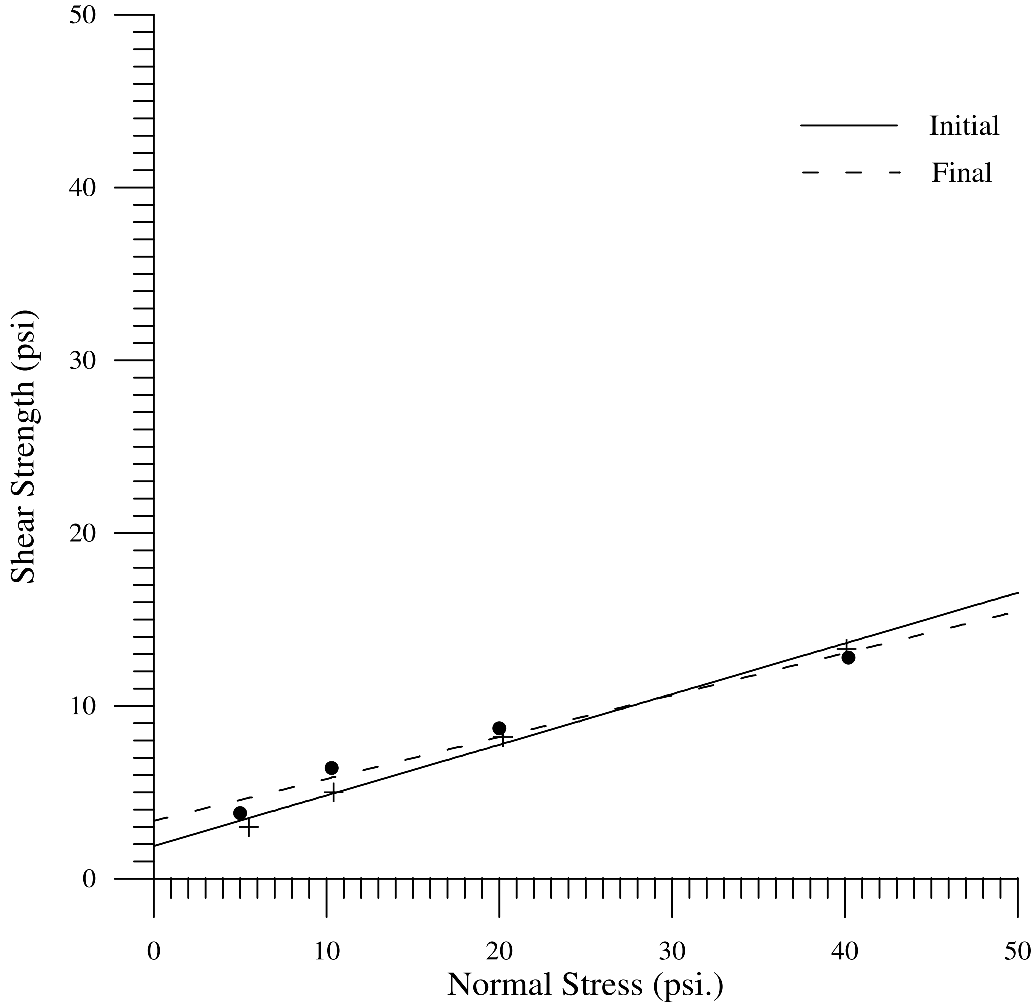

DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: S-3-A
Boring: RKS-35-08
Depth: 50.4-51.5'

DESCRIPTION
Contact between stiff greenish gray slickensided clay and altered meta-basalt.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	1.8	16.3
Final	3.3	13.6

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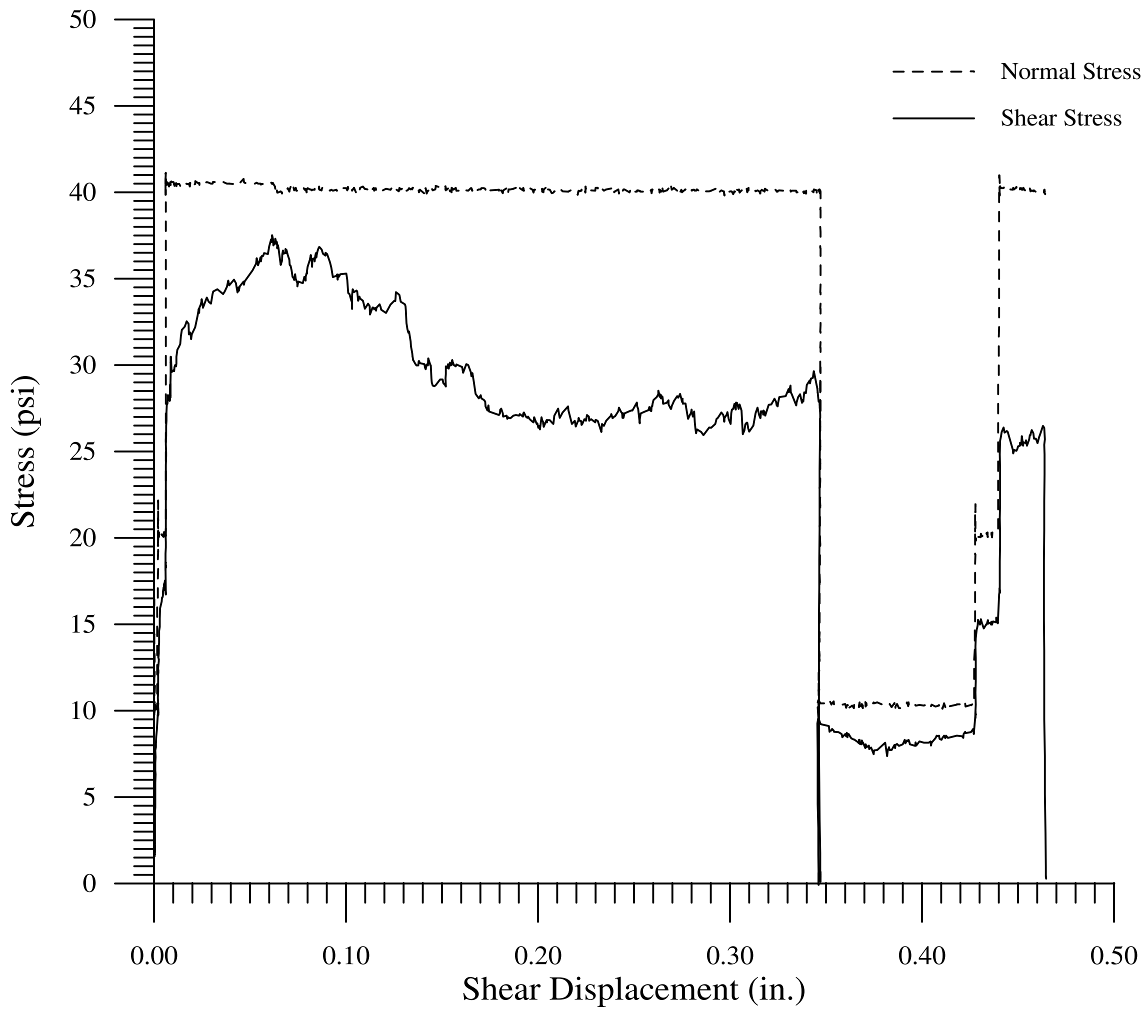

DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 101
Boring: RKS-39-08
Depth: 10.5-11.0'

DESCRIPTION

Slightly rough curved dark brown oxide coated joint in meta-lapilli tuff.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.2	8.8
	20.2	17.2
	40.4	28.2
Final	10.1	8.4
	20.2	15.0
	40.0	26.1

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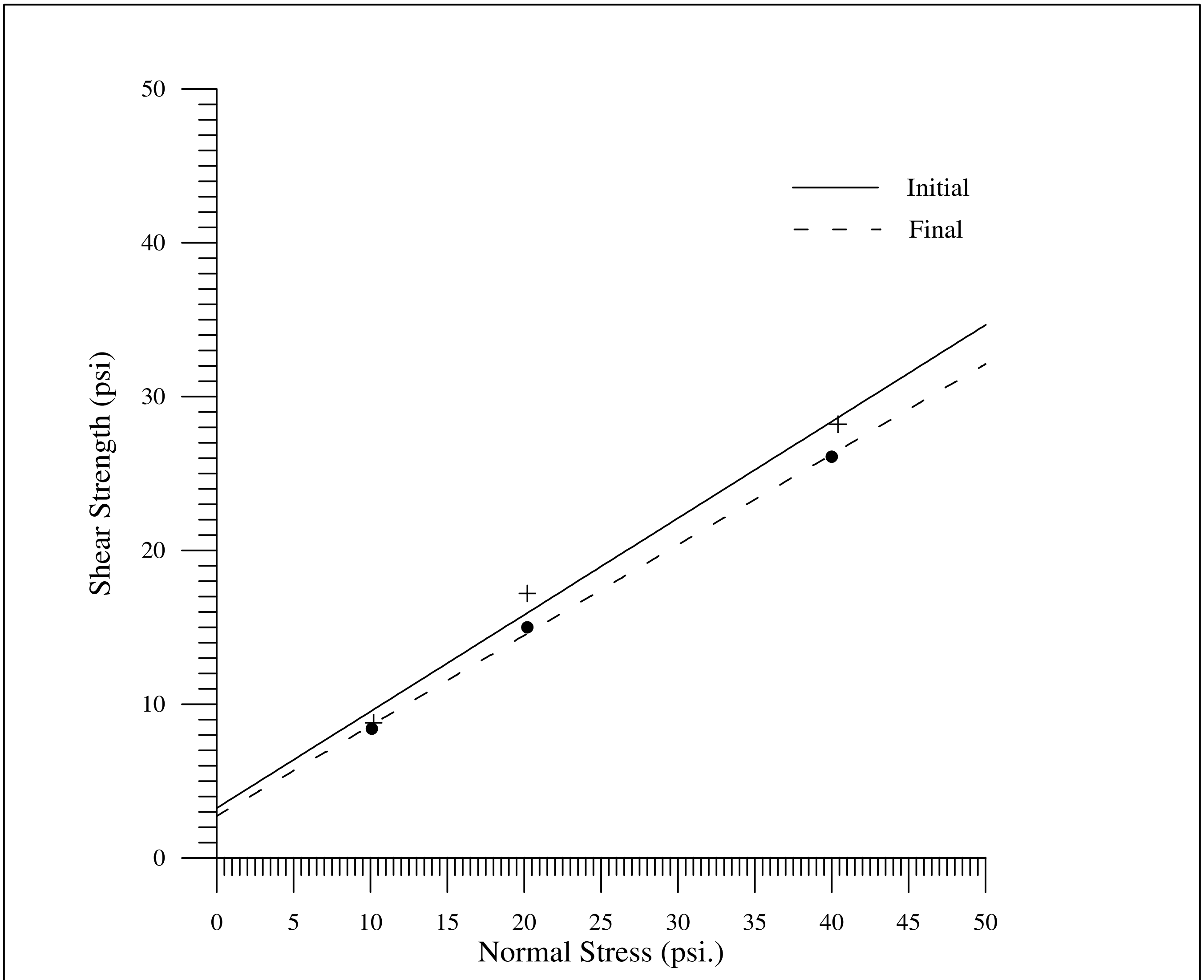
Project Number: 103WA

Test Date: **November 19, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 101
Boring: RKS-39-08
Depth: 10.5-11.0'

DESCRIPTION
Slightly rough curved dark brown oxide coated joint in meta-lapilli tuff.

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	3.2	32.1
Final	2.7	30.4

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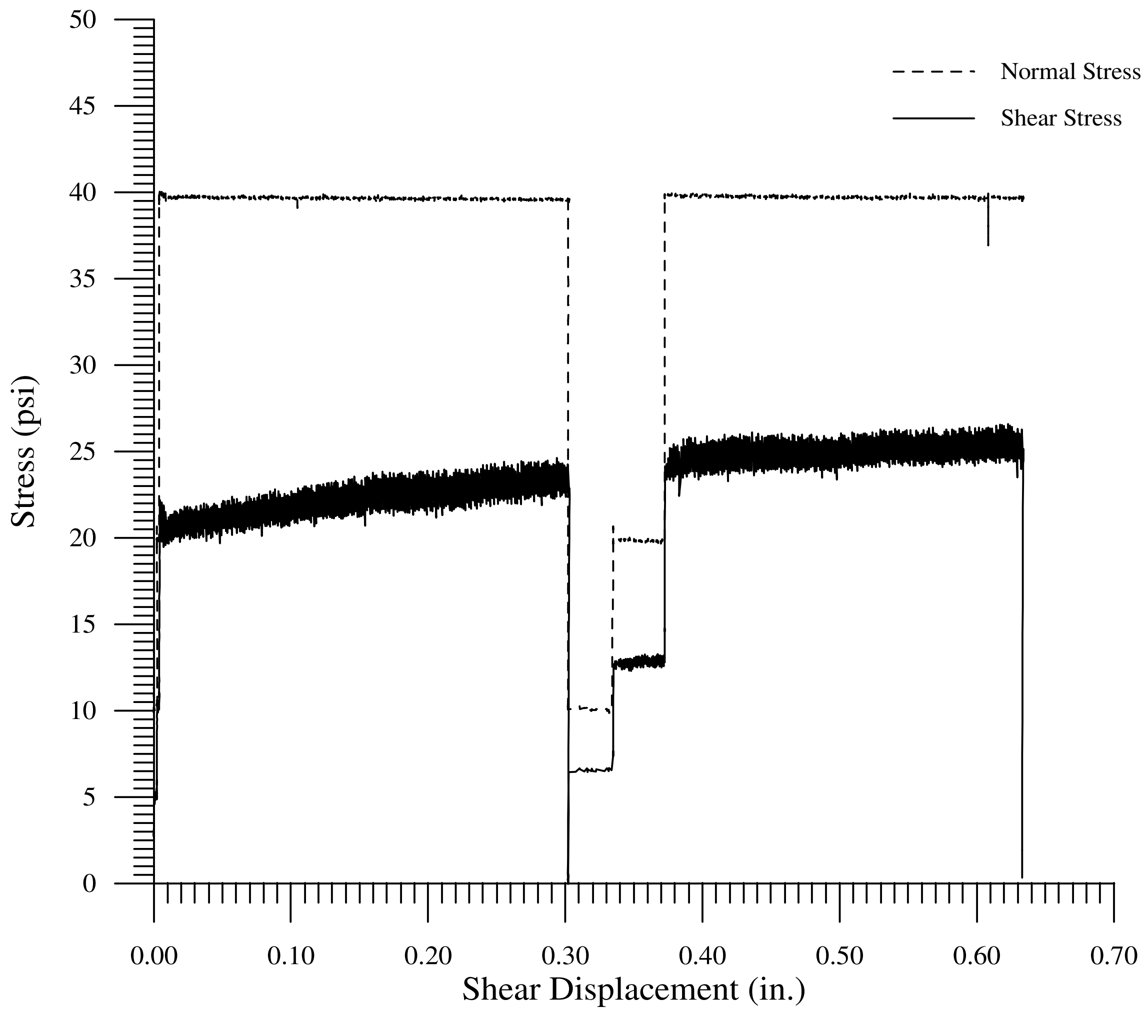
Project Number: 103WA

Test Date: **November 19, 2008**



DIRECT SHEAR TEST
Shear and Normal Stress vs. Shear Displacement

Sample: 103
Boring: RKS-47-08
Depth: 41.3-42.0'

DESCRIPTION

Saw-cut interface in light to medium gray quartzite.

	Normal Stress (psi)	Shear Strength (psi)
Initial	10.4	5.4
	20.0	10.4
	40.0	22.0
Final	10.0	6.5
	19.7	13.1
	39.7	25.8

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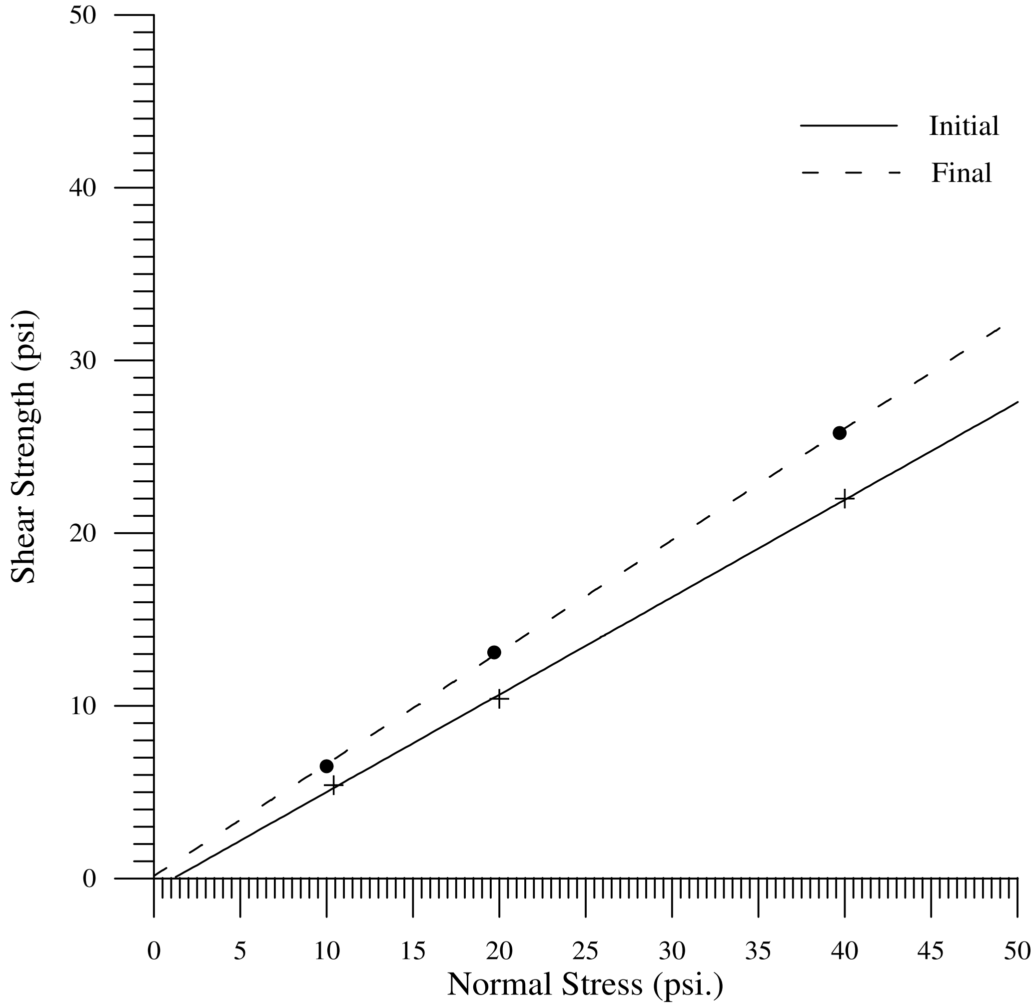
Project Number: 103WA

Test Date: **November 19, 2008**



DIRECT SHEAR TEST
Failure Envelope Normal Stress vs. Shear Strength

Sample: 103
Boring: RKS-47-08
Depth: 41.3-42.0'

DESCRIPTION
Saw-cut interface in light to medium gray quartzite

	Shear Intercept (psi)	Friction Angle (degrees)
Initial	NA (-0.6)	29.4
Final	0.2	32.9

Geo Test Unlimited
27069 N. Bloomfield Rd.
Nevada City, CA 95959

Client: **Wyllie & Norrish Engineers**
17918 NE 27th St.
Redmond, WA 98052

Project: **East I-90 Hyak Realignment**

Project Number: 103WA

Test Date: **November 19, 2008**


101-B
29.0-29.6'
Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-32-08 Depth: 29.0-29.6'
Sample: 101B


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-32-08 Depth: 29.0-29.6’
Sample: 101B


104-B
Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-33-08 Depth: 64.5-65.1’
Sample: 104-A


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-33-08 Depth: 64.5-65.1'
Sample: 104-A


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-34-08 Depth: 61.3-62.0'
Sample: S-2-A
61.3-62.0


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-34-08 Depth: 61.3-62.0'
Sample: S-2-A

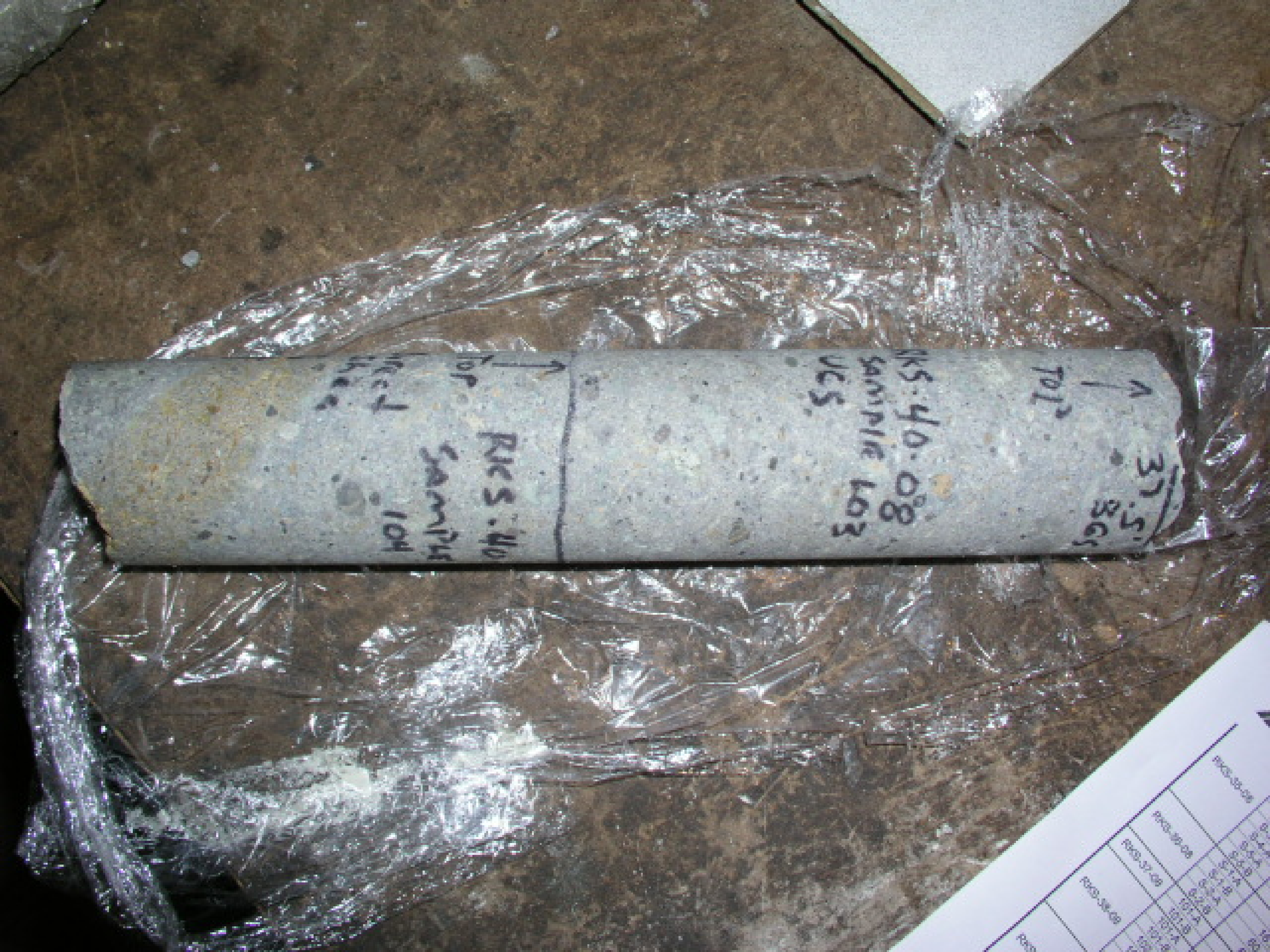

RKS-36-08
Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-36-08 Depth: 16.0-16.6’
Sample: S-1-B

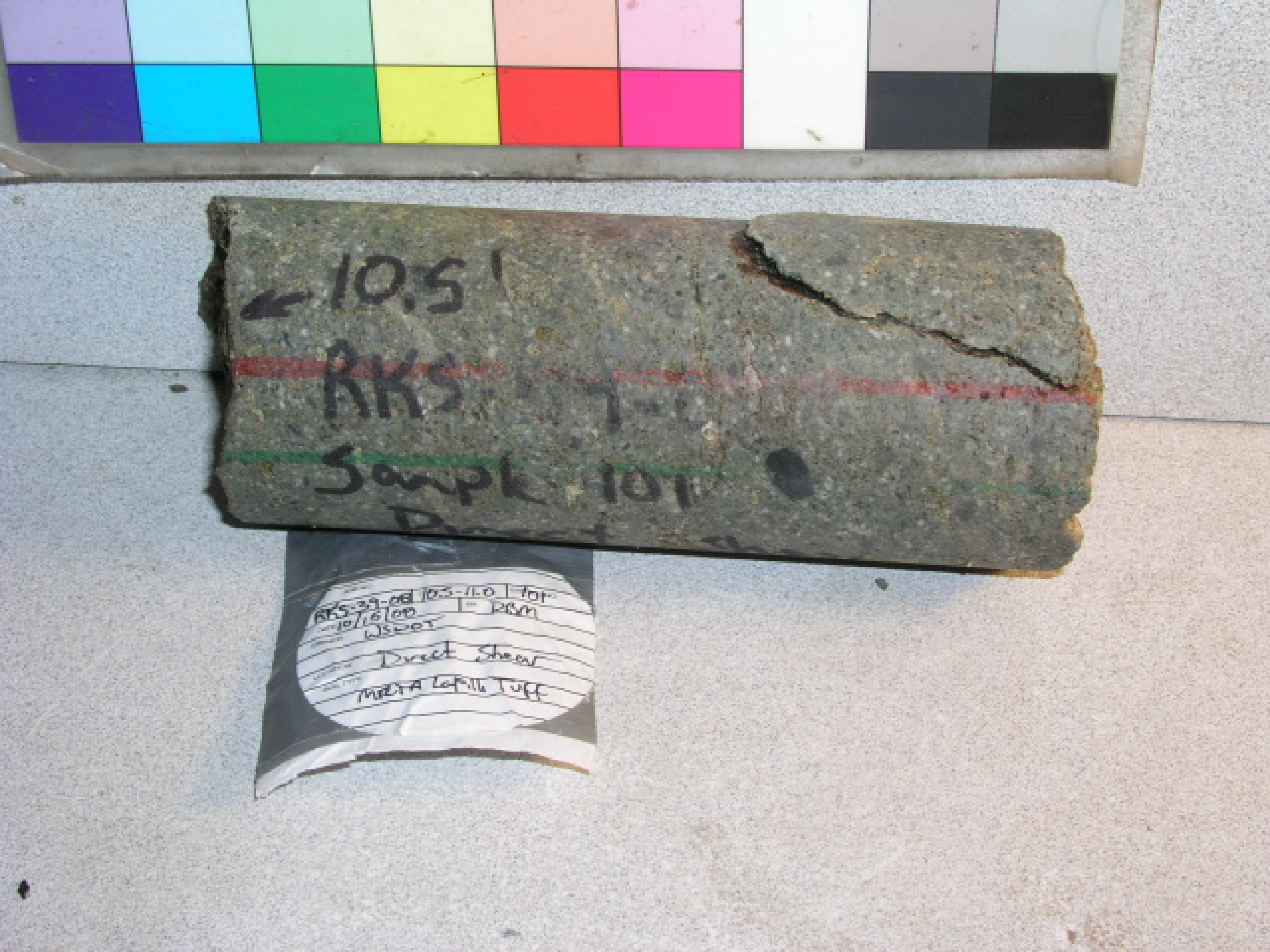

RKS-46-08
51.2-52.0'
#102
Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-46-08 Depth: 51.2-52.0'
Sample: 102


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-46-08 Depth: 51.2-52.0’
Sample: 102


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-47-08 Depth: 35.8-36.7’
Sample: 102


SAMPLE 102
Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Unconfined Compression Test
Boring: RKS-47-08 Depth: 35.8-36.7’
Sample: 102




10.5'
RKS
Sample 101
RKS-39-08 10.5-11.0 101
10/16/08 DBM
WSDOT
Direct Shear
Lapilli Tuff


KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black


KODAK Color Control Patches
Blue
Cyan
Green
Yellow
Red
Magenta
White
3/Color
Black


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-35-08 Depth: 43.3-44.0'
Sample: S-2-A
S-2-A


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-35-08 Depth: 43.3-44.0'
Sample: S-2-A


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-35-08 Depth: 50.4-51.5'
Sample: S-3-A


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-35-08 Depth: 50.4-51.5'
Sample: S-3-A


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-39-08 Depth: 10.5-11.0'
Sample: 101


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-39-08 Depth: 10.5-11.0’
Sample: 101


Wyllie & Norrish Rock Engineers
East I-90 Hyak Realignment
Direct Shear Test
Boring: RKS-47-08 Depth: 41.3-42.0'
Sample: 103

Corrosion Testing Results

Sunland Analytical

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 10/31/2007
Date Submitted 10/24/2007

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS-02-07 Site ID : 201/61-61.3'.
Thank you for your business.

* For future reference to this analysis please use SUN # 51984-103885.

EVALUATION FOR SOIL CORROSION

Soil pH	7.61	
Minimum Resistivity	1.34 ohm-cm (x1000)	
Chloride	14.9 ppm	00.00149 %
Sulfate	2.2 ppm	00.00022 %

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 10/31/2007
Date Submitted 10/24/2007

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS-06-07/RKS-11-07 Site ID : 104/102 COMPOS..
Thank you for your business.

* For future reference to this analysis please use SUN # 51984-103886.

EVALUATION FOR SOIL CORROSION

Soil pH	7.65	
Minimum Resistivity	0.64 ohm-cm (x1000)	
Chloride	12.8 ppm	00.00128 %
Sulfate	332.2 ppm	00.03322 %

METHODS

pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS 13-07 Site ID : 101.
Thank you for your business.

* For future reference to this analysis please use SUN # 52506-104990.

EVALUATION FOR SOIL CORROSION

Soil pH	6.88		
Minimum Resistivity	4.29	ohm-cm (x1000)	
Chloride	6.2 ppm	00.00062	%
Sulfate	1.5 ppm	00.00015	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS 13-07 Site ID : 103.
Thank you for your business.

* For future reference to this analysis please use SUN # 52506-104991.

EVALUATION FOR SOIL CORROSION

Soil pH	7.65		
Minimum Resistivity	1.37	ohm-cm (x1000)	
Chloride	6.5 ppm	00.00065	%
Sulfate	162.3 ppm	00.01623	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS 15-07 Site ID : 101.
Thank you for your business.

* For future reference to this analysis please use SUN # 52506-104992.

EVALUATION FOR SOIL CORROSION

Soil pH	5.91			
Minimum Resistivity	7.77	ohm-cm (x1000)		
Chloride	14.9	ppm	00.00149	%
Sulfate	1.3	ppm	00.00013	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS 19-07 Site ID : 101.
Thank you for your business.

* For future reference to this analysis please use SUN # 52506-104993.

EVALUATION FOR SOIL CORROSION

Soil pH	7.86		
Minimum Resistivity	0.51	ohm-cm (x1000)	
Chloride	46.2 ppm	00.00462	%
Sulfate	1105.1 ppm	00.11051	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS 23-07 Site ID : 104.
Thank you for your business.

* For future reference to this analysis please use SUN # 52506-104995.

EVALUATION FOR SOIL CORROSION

Soil pH	8.54		
Minimum Resistivity	3.48	ohm-cm (x1000)	
Chloride	6.0 ppm	00.00060	%
Sulfate	10.4 ppm	00.00104	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS 24-07 Site ID : 102.
Thank you for your business.

* For future reference to this analysis please use SUN # 52506-104996.

EVALUATION FOR SOIL CORROSION

Soil pH	8.18		
Minimum Resistivity	0.64 ohm-cm (x1000)		
Chloride	28.3 ppm	00.00283	%
Sulfate	293.5 ppm	00.02935	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : RKS 27-07 Site ID : 101.
Thank you for your business.

* For future reference to this analysis please use SUN # 52506-104997.

EVALUATION FOR SOIL CORROSION

Soil pH	8.13		
Minimum Resistivity	4.56	ohm-cm (x1000)	
Chloride	5.7 ppm	00.00057	%
Sulfate	2.6 ppm	00.00026	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : SI 2-07 Site ID : 102A.
Thank you for your business.

* For future reference to this analysis please use SUN # 52507-104998.

EVALUATION FOR SOIL CORROSION

Soil pH	7.98		
Minimum Resistivity	0.72 ohm-cm (x1000)		
Chloride	43.3 ppm	00.00433	%
Sulfate	315.0 ppm	00.03150	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : SI 2-07 Site ID : 105.
Thank you for your business.

* For future reference to this analysis please use SUN # 52507-104999.

EVALUATION FOR SOIL CORROSION

Soil pH	7.90	
Minimum Resistivity	0.86 ohm-cm (x1000)	
Chloride	11.2 ppm	00.00112 %
Sulfate	252.0 ppm	00.02520 %

METHODS

pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : SI-5-07 Site ID : 104.
Thank you for your business.

* For future reference to this analysis please use SUN # 52507-105000.

EVALUATION FOR SOIL CORROSION

Soil pH	7.70	
Minimum Resistivity	4.29 ohm-cm (x1000)	
Chloride	8.3 ppm	00.00083 %
Sulfate	20.1 ppm	00.00201 %

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : SI-9-07 Site ID : 203.
Thank you for your business.

* For future reference to this analysis please use SUN # 52507-105001.

EVALUATION FOR SOIL CORROSION

Soil pH	7.24		
Minimum Resistivity	4.56	ohm-cm (x1000)	
Chloride	13.9 ppm	00.00139	%
Sulfate	2.2 ppm	00.00022	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical

11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : SI-10-07 Site ID : 104.
Thank you for your business.

* For future reference to this analysis please use SUN # 52507-105002.

EVALUATION FOR SOIL CORROSION

Soil pH	8.10	
Minimum Resistivity	0.70 ohm-cm (x1000)	
Chloride	27.0 ppm	00.00270 %
Sulfate	271.9 ppm	00.02719 %

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Sunland Analytical
11353 Pyrites Way, Suite 4
Rancho Cordova, CA 95670
(916) 852-8557

Date Reported 02/08/2008
Date Submitted 02/05/2008

To: Norm Norrish
Wyllie & Norrish Rock Eng.
17918 NE 27th St.
Redmond, WA 98052

From: Gene Oliphant, Ph.D. \ Randy Horney
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : SI 12-07 Site ID : 102.
Thank you for your business.

* For future reference to this analysis please use SUN # 52507-105003.

EVALUATION FOR SOIL CORROSION

Soil pH	7.72	
Minimum Resistivity	3.48 ohm-cm (x1000)	
Chloride	8.1 ppm	00.00081 %
Sulfate	10.1 ppm	00.00101 %

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422

Atterberg Limits Testing Results

Vector Engineering

VECTOR ENGINEERING, INC.
An Ausenco group company

DATE: January 2, 2009

TO: Norm Norrish
Wyllie & Norrish Rock Engineers
17918 NE 27th Street
Redmond, WA 98052

e-mail: nnorrish@wnrockeng.com, abro.gtu@gmail.com

JOB NO: 081717.00
LAB LOG: 2716.0

RE: **Lab Report: I 90 East Hyak Realignment**

Enclosed are results for: Samples Received - December 11, 2008

Code	Item	Quantity
19534	Atterberg Limits, ASTM D-4318	4

Thank you for consulting Vector Engineering for your material testing requirements. We look forward to working with you again. If you have any questions or require any additional information, please call us at 1-530-272-2448.

Sincerely,

Duane Nava
Prepared By: Duane Nava
Laboratory Manager

M Dell-Era
Reviewed By: Margaret Dell-Era
Laboratory Administrator

Vector Engineering Inc.

143E Spring Hill Drive, Grass Valley, CA 95945 (530) 272-2448

LABORATORY SERVICES

ATTERBERG LIMITS

Summary Report

ASTM D-4318

Client : Wyllie & Norrish Rock Engineers

Project No: 081717.00

Lab Log No.: **2716**

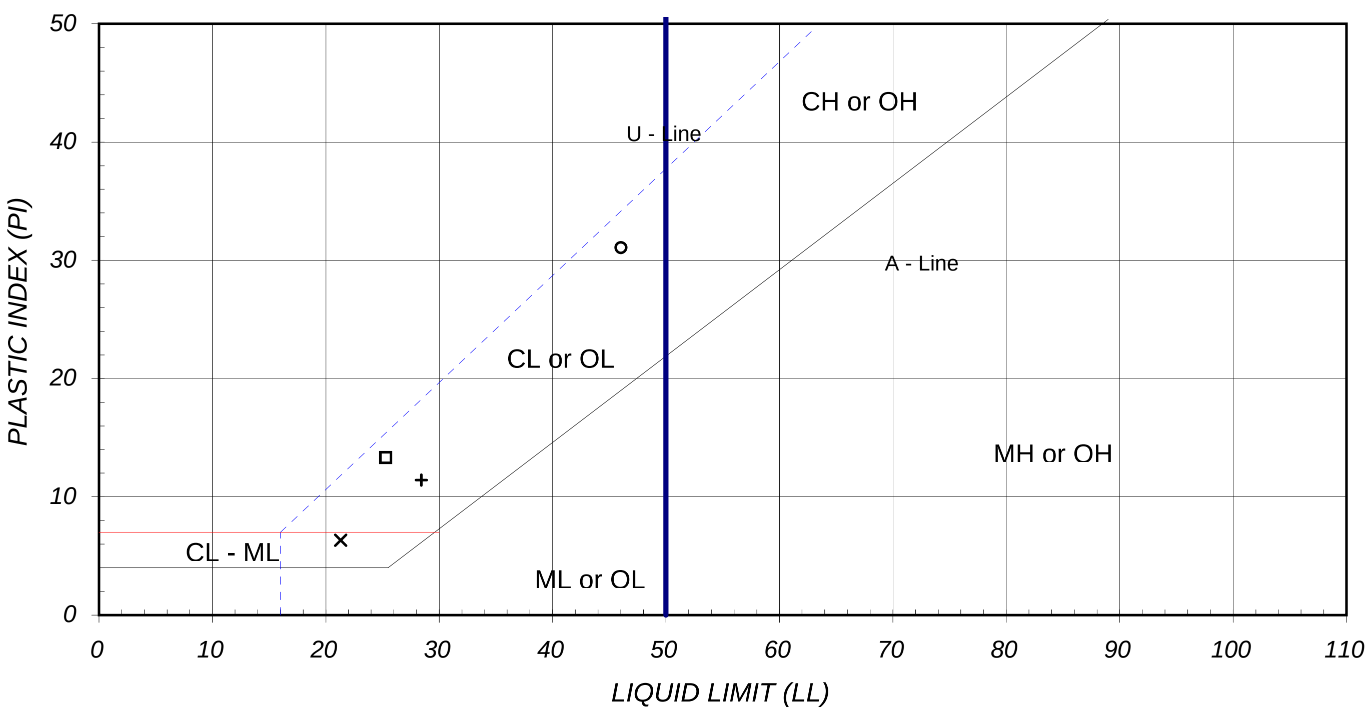
Project Name: I 90 East Hyak Realignment

Report Date: January 2, 2008

LSN	SYMBOL	SAMPLE IDENTIFICATION	SAMPLE DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	PLASTIC INDEX
2716A	□	RKS-34-08, S-3-A, 68.7-69.4	Red Brown Lean Clay w/ Sand (CL)	25	12	13
2716B	○	RKS-35-08, S-3-A, 50.4-51.5	Light Brown Lean Clay w/ Sand (CL)	46	15	31
2716C	+	RKS-41-08, 104, 75.5-76.3	Brown Sandy Lean Clay (CL)	28	17	11
2716D	x	RKS-42-08, 101, 26.7-27.6	Gray Sandy Silty Clay (CL-ML)	21	15	6

* Visual Classification based on ASTM D-2488

PLASTICITY CHART



Petrographic Analysis Results

Spectrum Petrographics of Vancouver, Washington and Dr. Robert Burk (Burk GeoConsult, LLC) contributed to the petrographic work, and Dr. Ray Ingersoll Professor of Geology at University of California at Los Angeles reviewed that work.

Key to Petrographic and Photomicrographic Descriptions

Clay minerals common in altered rocks must often be identified by X-ray diffraction either because their optic properties are not diagnostic or because they are too fine grained to be reliably identified by optical methods. The term "clay" is used herein to denote fine grained phyllosilicates in general. Under ideal conditions, it is often possible to optically discriminate between 4 major groups: kaolinite, smectite, mica (including illite), and chlorite. This is done whenever conditions permit.

The term "sericite" is applied to fine grained colorless phyllosilicates that show upper 2^{nd} order maximum interference colors. These could include muscovite, illite, paragonite, lepidolite, margarite, clintonite, pyrophyllite, and talc. The term "intermediate clay" is applied to fine grained very pale or colorless phyllosilicates that show upper 1st order maximum interference colors. These are probably dominated by chlorite, smectite, and mixed-layer illite/smectite.

The term "opaques" is used to refer to all materials opaque (and sometimes semi-opaque) to transmitted light. The term "FEOH" is herein used to indicate fine grained, yellowish to reddish brown, earthy materials of varying opacity in transmitted light. FEOH is probably mostly Fe oxyhydroxides but may sometimes include sphalerite, realgar, orpiment, jarosite, a number of Mn oxyhydroxides, and organic matter.

A question mark after a rock or mineral name in a petrographic description means that there is uncertainty about the identification of that rock or mineral.

Particle size distributions are given as (A-B □m), where A and B are the median and largest particle sizes, respectively, in microns. A question mark (?) in the position of A or B indicates that the value of A or B was indeterminate, probably because of excessively large or small particle size or statistically insignificant numbers of particles.

Mineral abundances are visual estimates for an entire slide. For multi-lithologic materials (cuttings, etc...), mineralogy, textures, and alteration are described only for the dominant lithology.

Section preparation codes are as follows: (1) Format: 27 x 46 mm, 51 x 76 mm, or 1" round; (2) Finish: standard lapping (STD) or polished (POL); (3) Stains: sodium cobaltinitrite (SCN), alizarin red S (ARS), potassium ferricyanide (PF), and barium chloride + potassium rhodizonate (BCPR); and (4) Cover: none, permanent Loctite acrylic (PLA), or removable Canada Balsam (RCB).

Photomicrograph captions/labels contain the following items of information in consecutive order separated by forward slashes: (1) sample identification; (2) film roll number; (3) frame number; (4) illumination; (5) field of view (FOV); and (6) the job identification number. "PPL" indicates plane-polarized light; "XPL indicates cross-polarized light; "R" indicates reflected light. "550" means that a 550 nanometer wavelength plate was inserted in the light path. "C" indicates that the substage condenser was in (sometimes used for Fe-oxides). "O" indicates substage condenser in an oblique position. These various illuminations can be combined. "CON" indicates conoscopic illumination. POL means that a polarizing filter was used with the lens, and DAY means the sample was photographed in diffused daylight.

Features on photomicrographs are indicated by the number of the feature in the ALTERATION section of the text or by a mineral name abbreviation: **Q**uartz, **P**lagioclase, **K**feldspar,**ser**icite, **b**io**t**ite, **fe**rroan **c**al**c**ite, **act**inolite.

Thin section descriptions are based on work by Spectrum Petrographics and Burk GeoConsult, with review by Dr. Ray Ingersoll, UCLA.

SAMPLE # **RKS-09-07 #201**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + FEOH + prehnite + opaques) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (35%) + plagioclase (31%) + quartz (25%) + clay (5%) + FEOH (2%) + prehnite (1%) + opaques (1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1.2-5.6 mm, angular to subangular. Contacts between framework components are floating to tangential.

Phenocryst Fragments (38%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (28%) + quartz (10%)].

Lithic Fragments (12%) are composed of basalt and dacite vitrophyre.

Pumice Fragments (0%) were not observed.

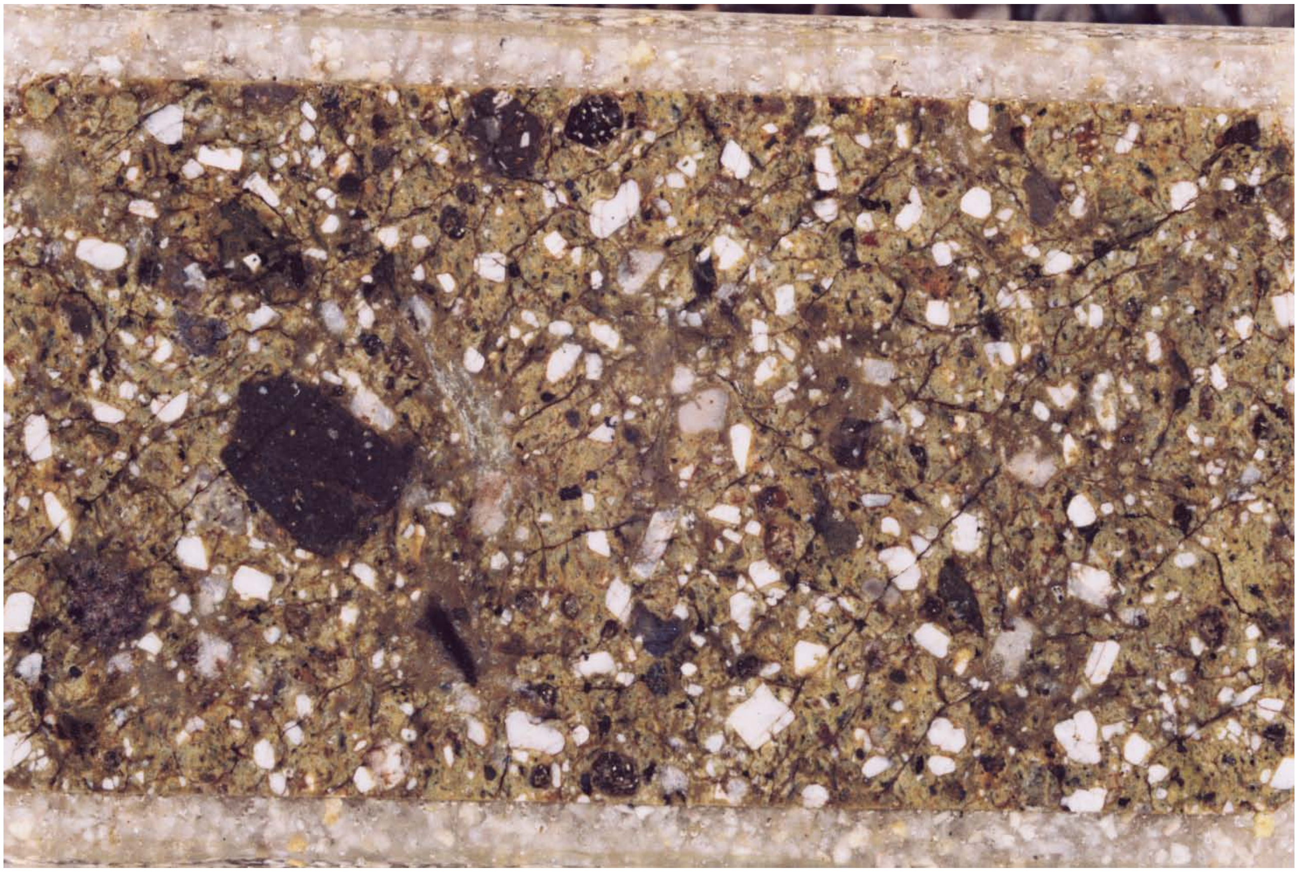
Matrix/Cement (50%) is composed of weakly welded devitrified K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately devitrified to quartz; and (2) plagioclase weakly altered to clay + prehnite; and (3) veins of FEOH.

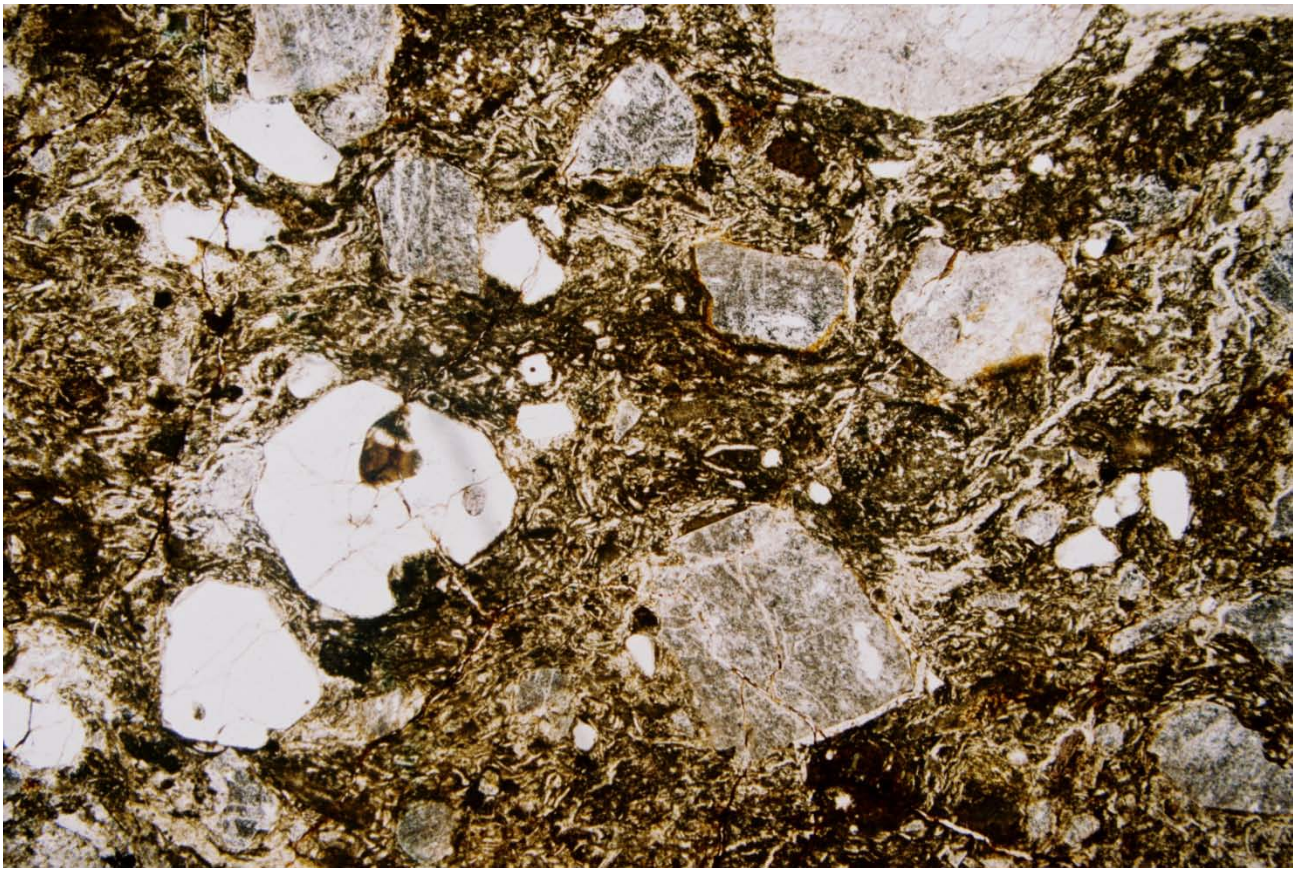
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

RKS-09-07#201 07041/20/DAY/3X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



RKS-09-07#201 07052/18/PPL/28X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of weakly welded devitrified glass shards.



SAMPLE # **RKS-09-07 #202**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + chlorite + unknown A + opaques + prehnite + FEOH) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (35%) + plagioclase (30%) + quartz (22%) + clay (5%) + chlorite (2%) + unknown A (2%) + opaques (2%) + prehnite (1%) + FEOH (1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1.0-5.6 mm, angular to subangular. Contacts between framework components are floating to tangential.

Phenocryst Fragments (40%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (32%) + quartz (8%)].

Lithic Fragments (10%) are composed of basalt and dacite vitrophyre.

Pumice Fragments (0%) were not observed.

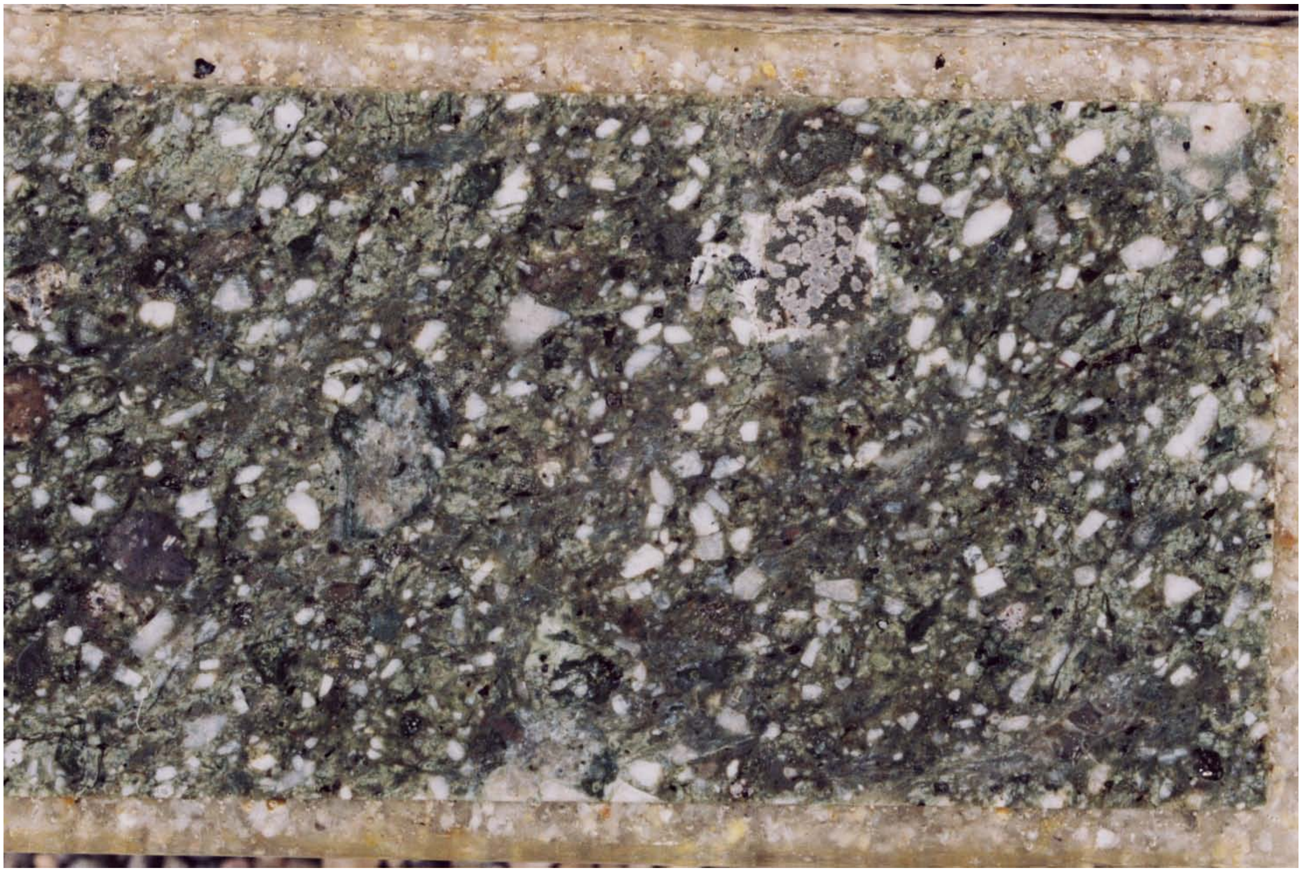
Matrix/Cement (50%) is composed of weakly welded devitrified K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately devitrified to quartz; (2) plagioclase weakly altered to clay + prehnite; and (3) veins of unknown A.

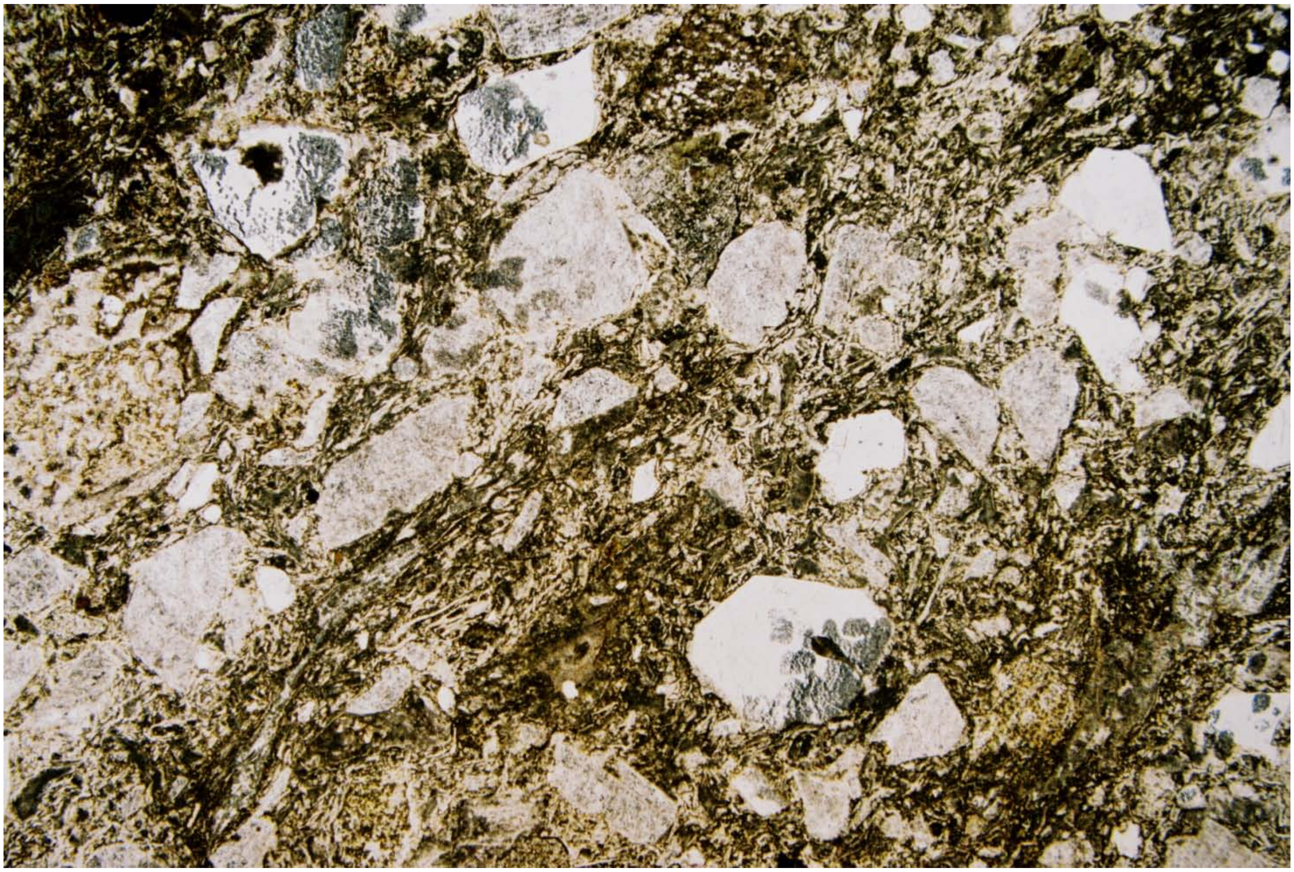
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

RKS-09-07#202 07041/21/DAY/3X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



RKS-09-07#202 07052/19/PPL/28X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of weakly welded devitrified glass shards.



SAMPLE # **RKS-12-07 #201**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + opaques + chlorite + epidote) of a welded dacite ash-flow tuff protolith.

MINERALS Plagioclase (41%) + cryptocrystalline devitrified K-glass (35%) + quartz (25%) + clay (5%) + opaques (2%) + chlorite (1%) + epidote (1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1.0-4.2 mm, angular to subangular. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (30%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (20%) + quartz (10%)].
>
> **Lithic Fragments (17%)** are composed of basalt and dacite vitrophyre.
>
> **Pumice Fragments (3%)** are porphyritic dacite.

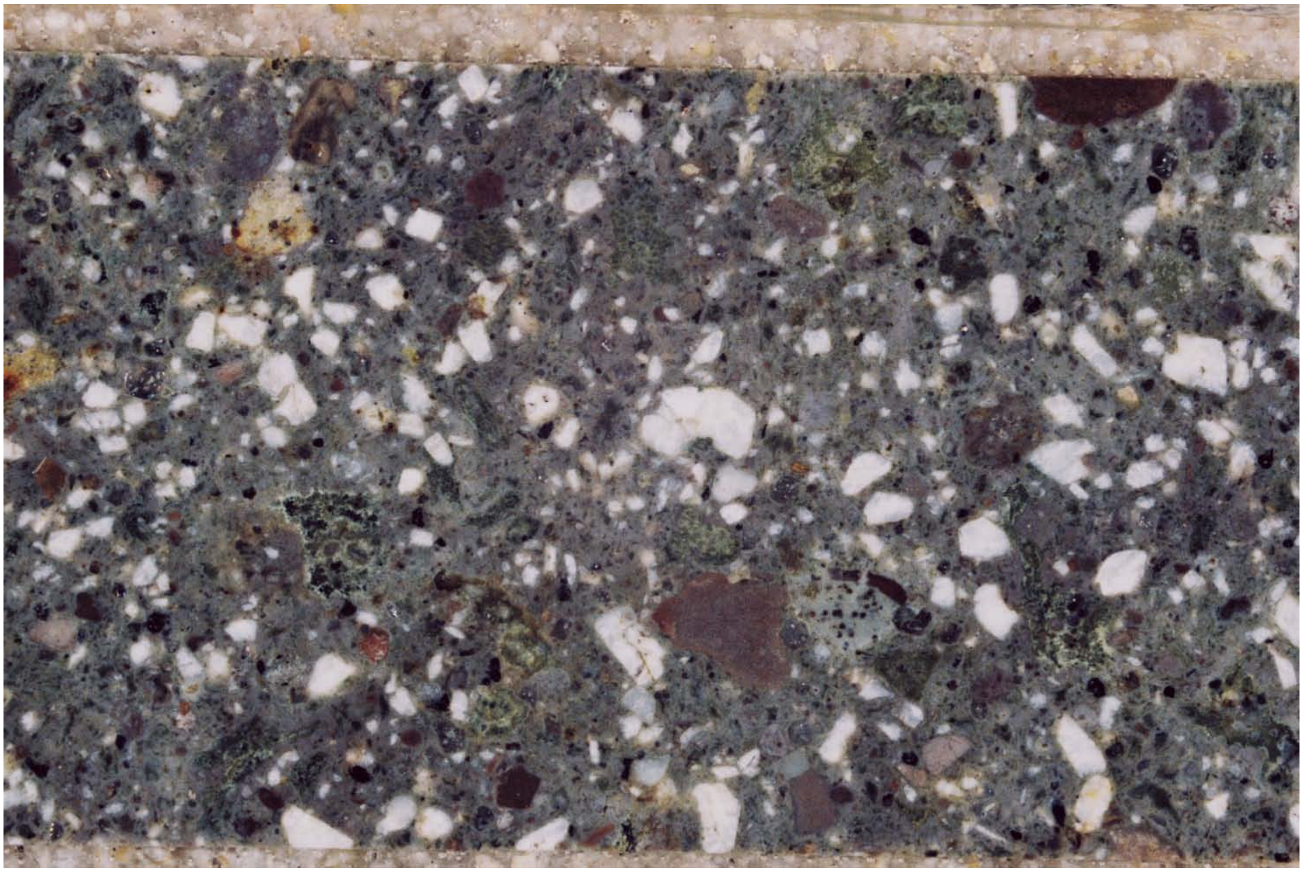
Matrix/Cement (50%) is composed of weakly welded devitrified K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately devitrified to quartz; and (2) plagioclase weakly altered to clay ± epidote.

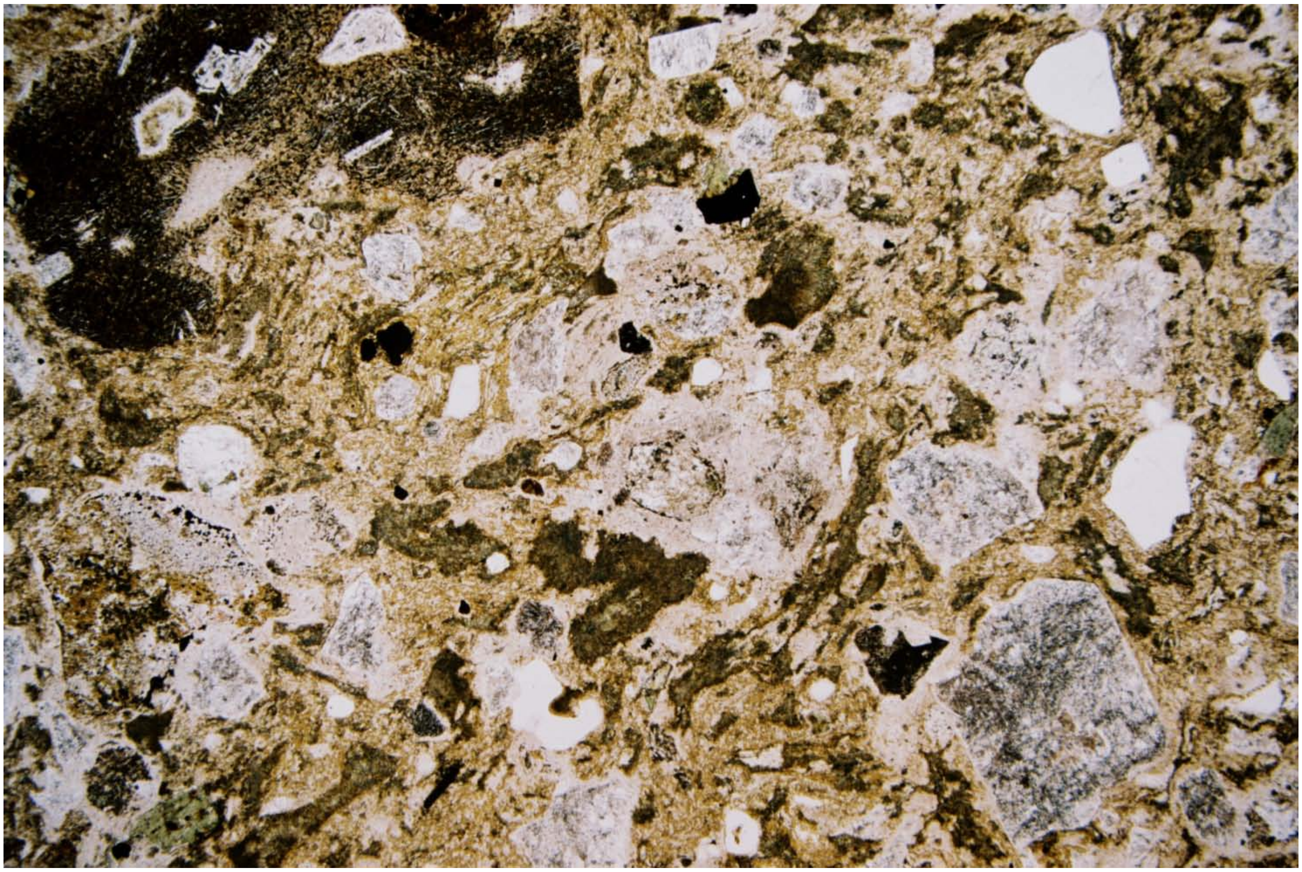
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

RKS-12-07#201 07041/22/DAY/3X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



RKS-12-07#201 07052/20/PPL/28X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of weakly welded devitrified glass shards.



SAMPLE # **RKS-12-07 #202**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + ferroan calcite + opaques + chlorite) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (35%) + plagioclase (31%) + quartz (23%) + clay (5%) + ferroan calcite (3%) + opaques (2%) + chlorite (1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

<u>Framework Components (50%)</u> are 1.2-12 mm, angular to subangular. Contacts between framework components are floating to tangential.

Phenocryst Fragments (27%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (19%) + quartz (8%)].

Lithic Fragments (20%) are composed of basalt and dacite vitrophyre and dacite ash-flow tuff.

Pumice Fragments (3%) are composed of porphyritic dacite.

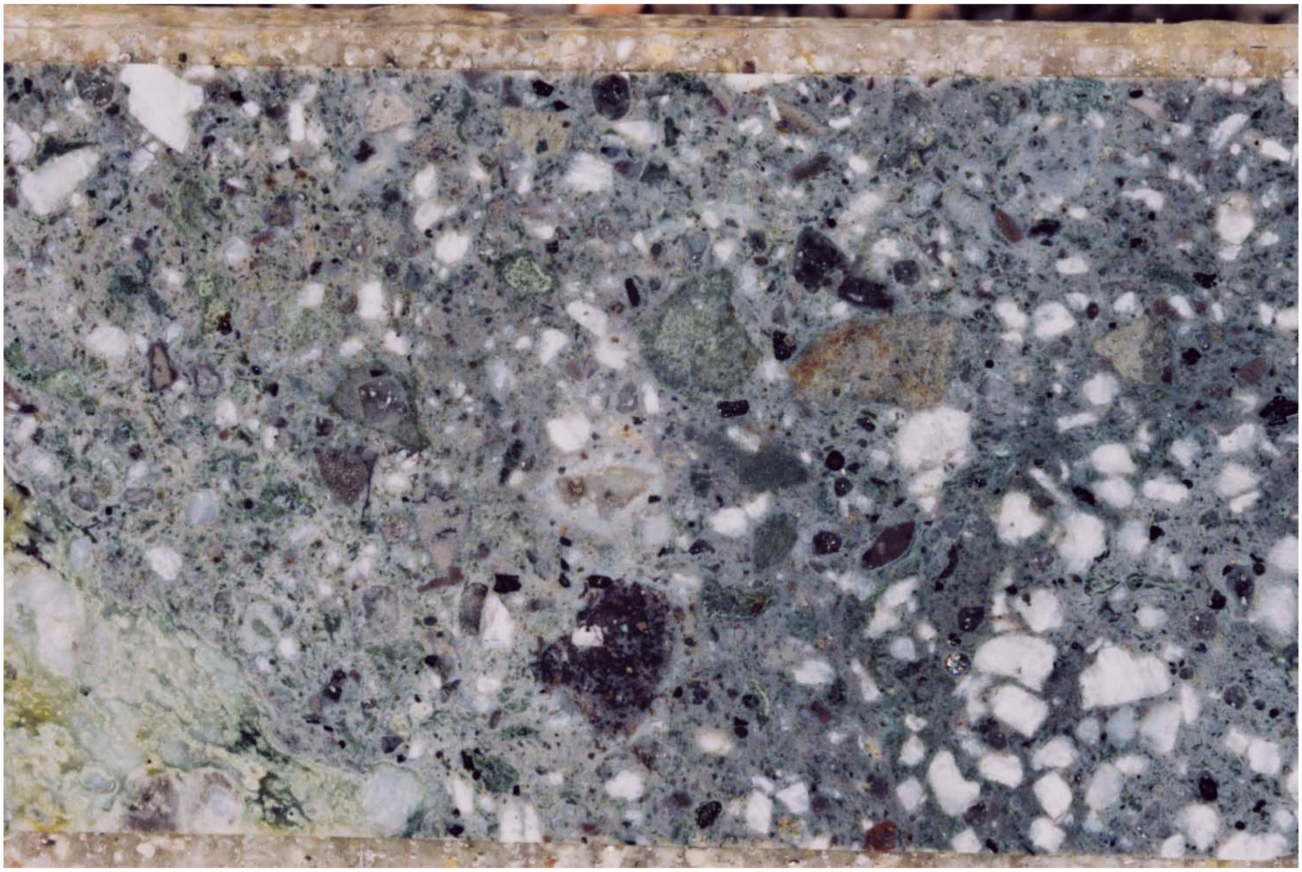
<u>Matrix/Cement (50%)</u> is composed of weakly welded devitrified K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately devitrified to quartz; and (2) plagioclase weakly altered to clay + ferroan calcite.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

RKS-12-07#202 07041/23/DAY/3X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



RKS-12-07#202 07052/21/PPL/28X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of weakly welded devitrified glass shards.

SAMPLE # **RKS-12-07 #203**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + ferroan calcite + opaques + chlorite) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (35%) + plagioclase (26%) + quartz (25%) + clay (7%) + ferroan calcite (3%) + opaques (2%) + chlorite (2%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1.0-12 mm, angular to subangular. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (25%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (15%) + quartz (10%)].
>
> **Lithic Fragments (20%)** are composed of basalt and dacite vitrophyre.
>
> **Pumice Fragments (5%)** are composed of porphyritic dacite.

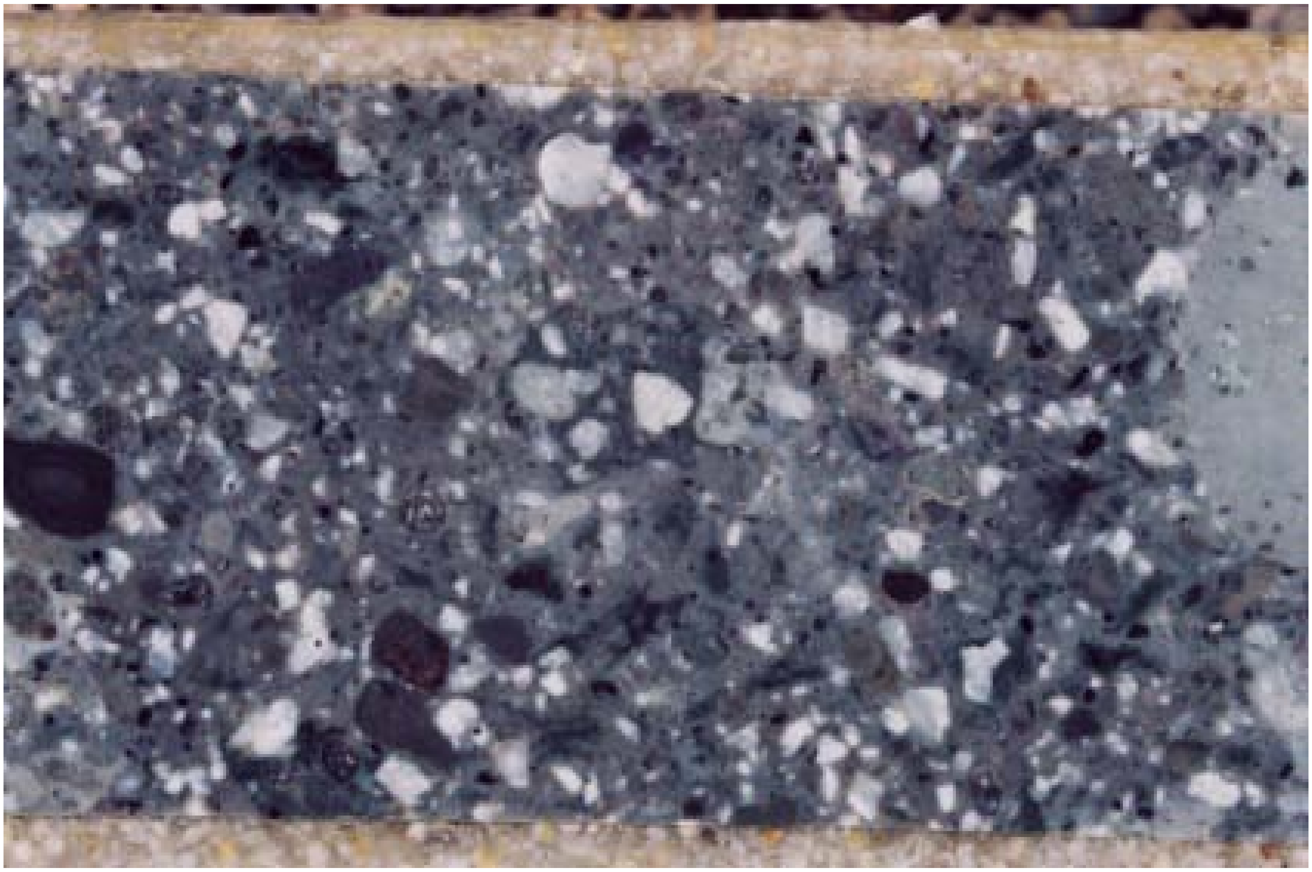
Matrix/Cement (50%) is composed of weakly welded devitrified K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately devitrified to quartz; (2) plagioclase weakly altered to clay + ferroan calcite; and (3) veinlets of ferroan calcite.

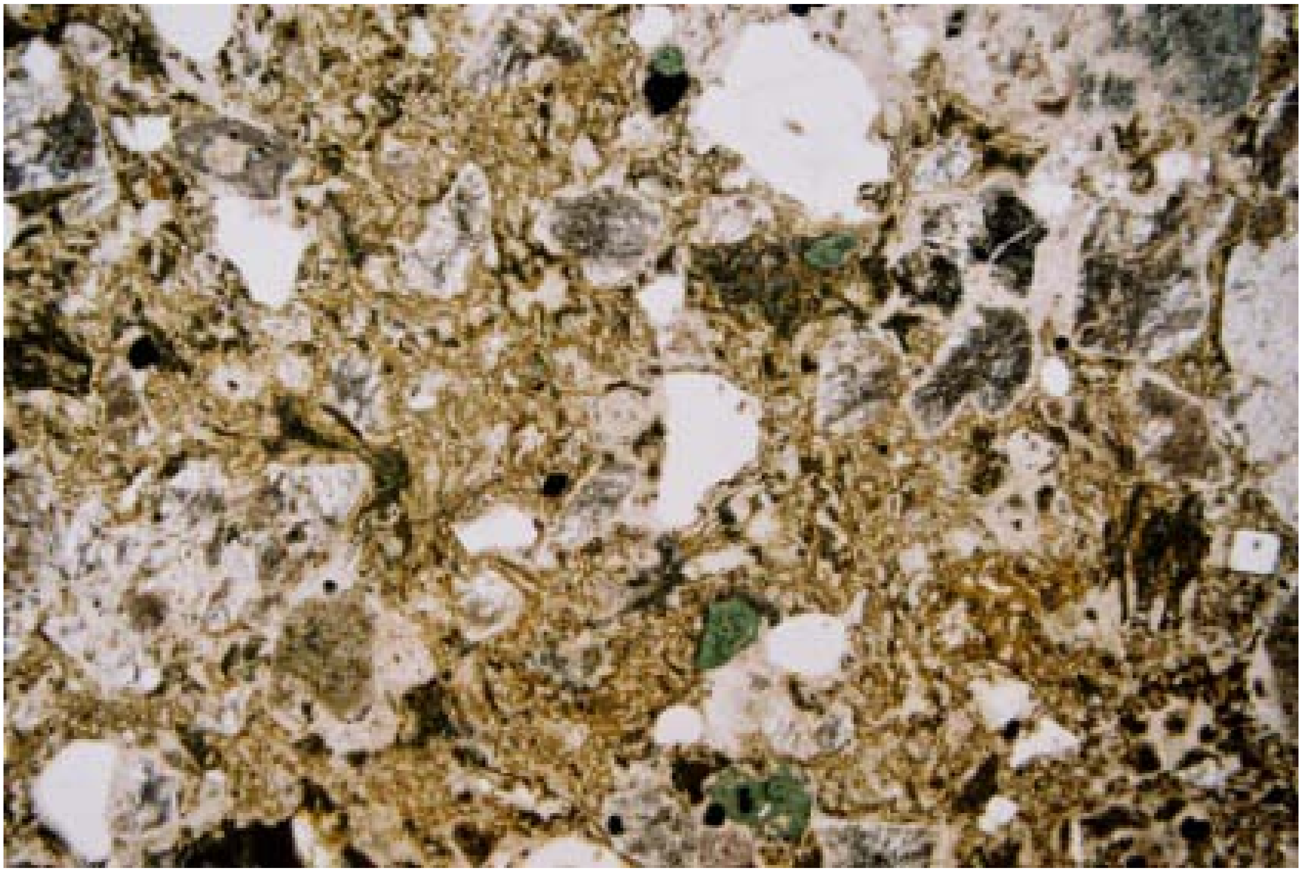
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

RKS-12-07#203 07041/24/DAY/3X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



RKS-12-07#203 07052/22/PPL/28X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of weakly welded devitrified glass shards.



SAMPLE # **RKS-18-07 #201**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + chlorite + opaques + epidote + prehnite) of a welded dacite ash-flow tuff protolith.

MINERALS Plagioclase (33%) + cryptocrystalline devitrified K-glass (30%) + quartz (25%) + clay (5%) + chlorite (4%) + opaques (2%) + epidote (1%) + prehnite (<1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

<u>Framework Components (55%)</u> are 1.2-9.6 mm, angular to subangular. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (27%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (17%) + quartz (10%)].
>
> **Lithic Fragments (25%)** are composed of basalt and dacite vitrophyre.
>
> **Pumice Fragments (3%)** are composed of porphyritic dacite.

<u>Matrix/Cement (45%)</u> is composed of weakly welded devitrified K-glass moderately devitrified to quartz.

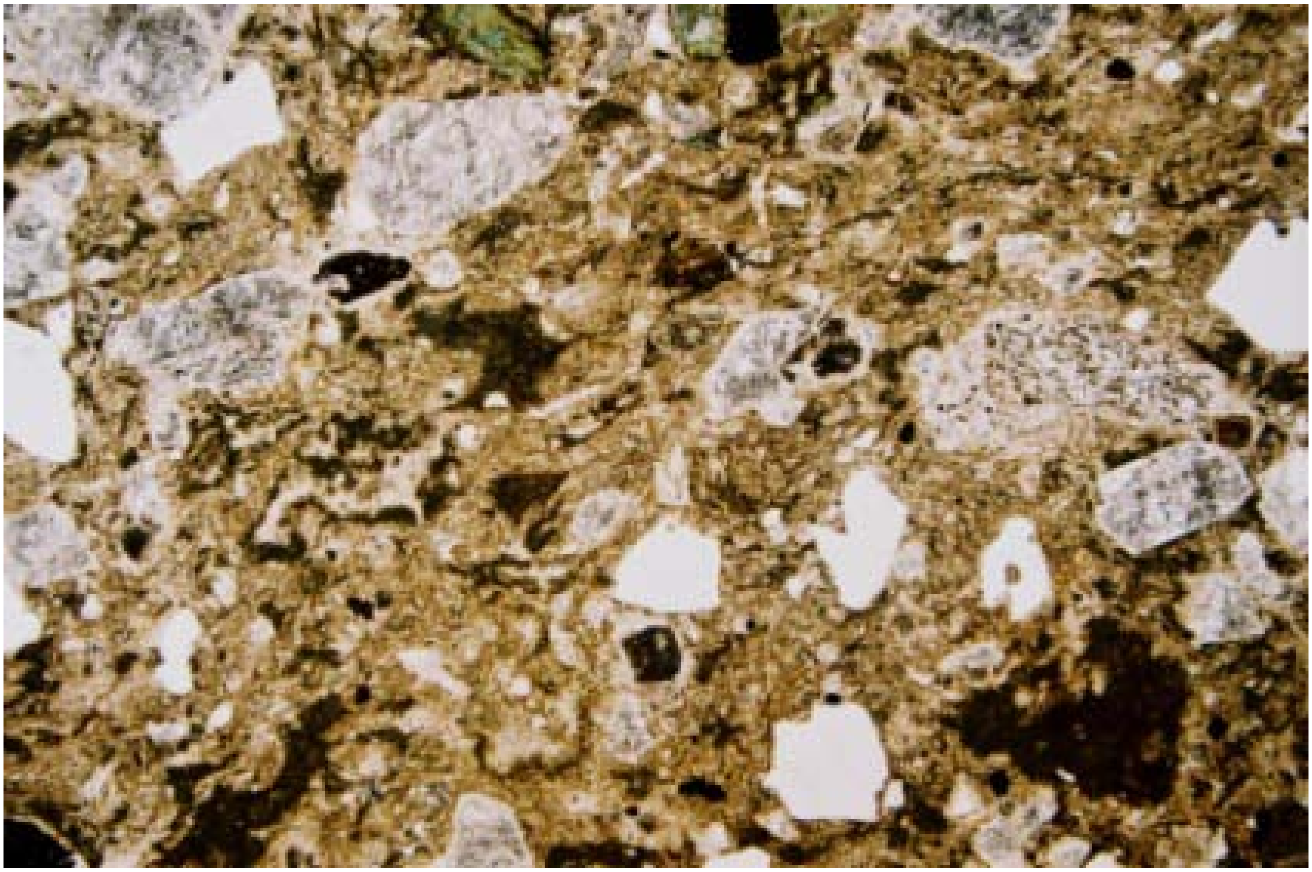
ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately devitrified to quartz; (2) plagioclase weakly altered to clay ± prehnite; and (3) veinlets of FEOH.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

RKS-18-07#201 07041/25/DAY/3X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.

RKS-18-07#201 07052/23/PPL/28X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of weakly welded devitrified glass shards.



SAMPLE # **RKS-18-07 #202**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + chlorite + opaques + epidote + prehnite) of a welded dacite ash-flow tuff protolith.

MINERALS Plagioclase (30%) + cryptocrystalline devitrified K-glass (30%) + quartz (25%) + clay (5%) + ferroan calcite (5%) + chlorite (3%) + opaques (2%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1-4 mm, angular to subangular. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (22%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (22%) + quartz (10%)].
>
> **Lithic Fragments (15%)** are composed of basalt and dacite vitrophyre.
>
> **Pumice Fragments (3%)** are composed of porphyritic dacite.

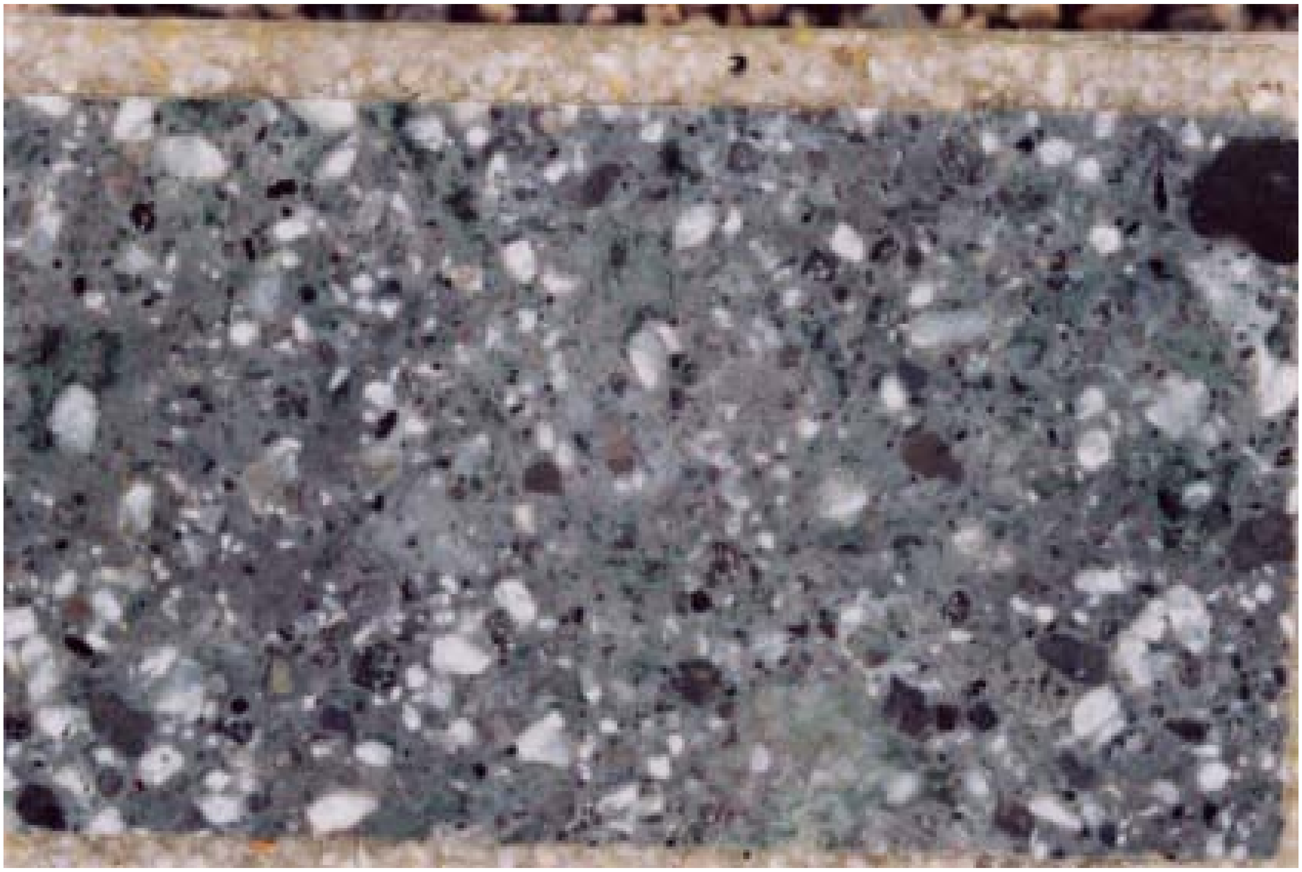
Matrix/Cement (50%) is composed of weakly welded devitrified K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately devitrified to quartz; and (2) plagioclase weakly altered to clay.

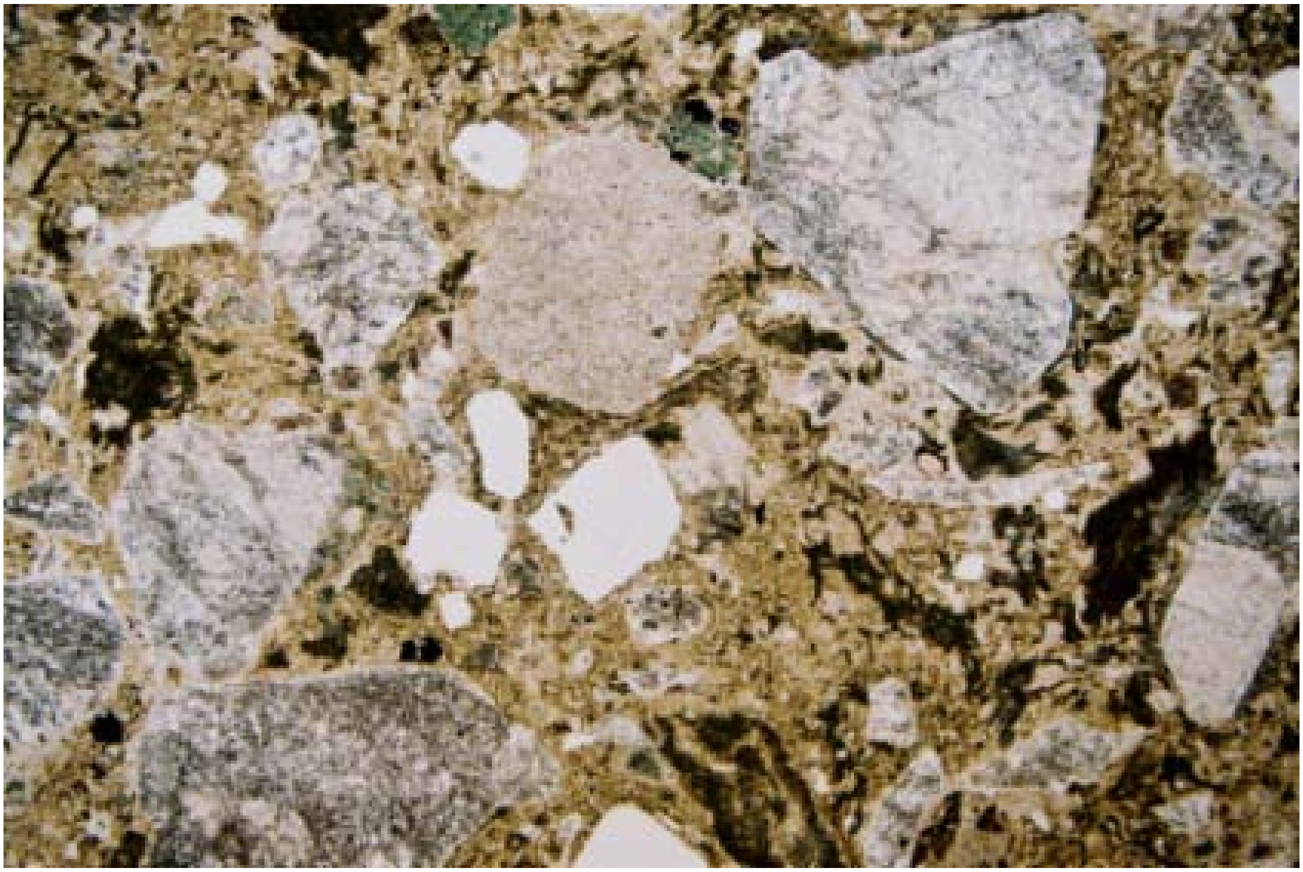
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

RKS-18-07#202 07042/01/DAY/3X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



RKS-18-07#202 07052/24/PPL/28X/ULC ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of weakly welded devitrified glass shards.



SAMPLE # **RKS-46-08 201**

ROCK NAME ALTERED PORPHYRITIC BASALT or ANDESITE -- probably formed by alteration (secondary K-feldspar + weakly ferroan calcite + quartz + chlorite) of a porphyritic basalt flow.

MINERALS Plagioclase (35%) + K-feldspar (35%) + opaques (15%) + weakly ferroan calcite (7%) + quartz (5%) + chlorite (3%).

TEXTURES Phaneritic, holocrystalline, porphyritic, fine to medium grained, non directed fabric.

Phenocrysts (20%) subhedral to euhedral, whole, isolated to glomeroporphyritic, 1000-1800 μm.

Plagioclase (20%) weakly altered to weakly ferroan calcite + K-feldspar.

Groundmass (80%) has an intergranular texture and is composed of [plagioclase strongly altered to K-feldspar] + opaques.

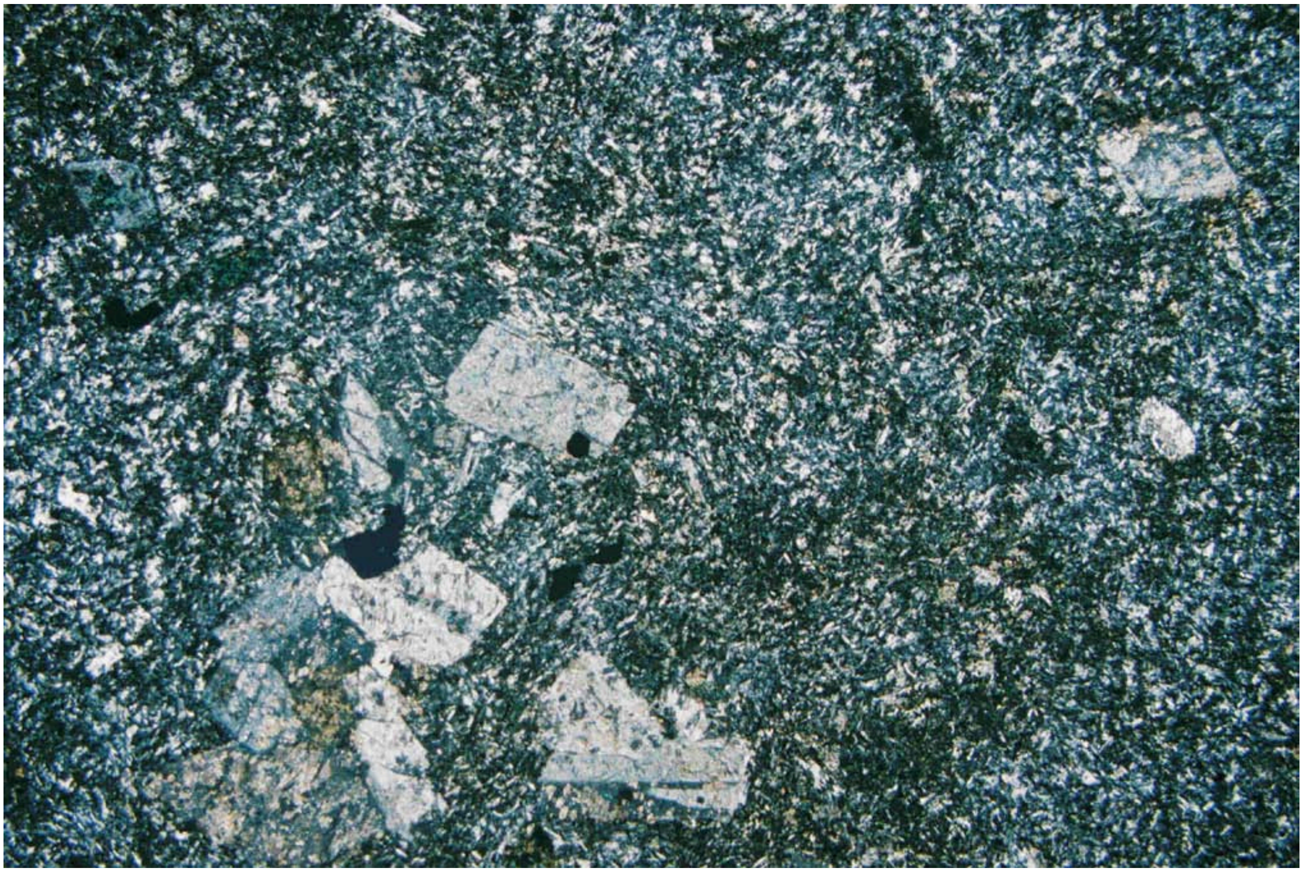
Vesicles (0%) and Xenoliths (0%) were not observed.

ALTERATION Mineralized by weakly ferroan calcite + chlorite + quartz.

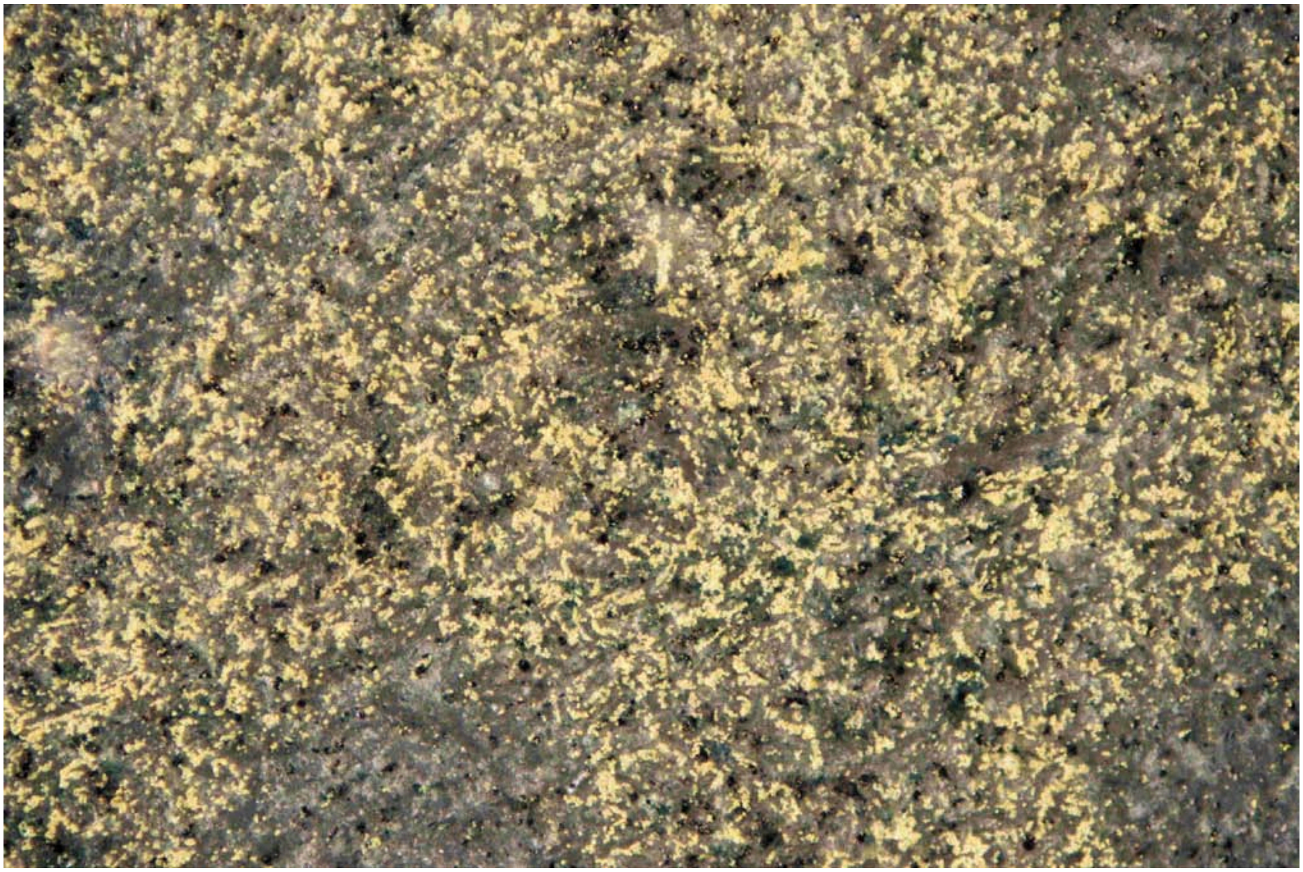
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA

PHOTOS Refer to next (2) pages.

RKS-46-08 201 08045_18m.jpg/X/FOV = 4.00 x 5.83 mm/WCF ALTERED PORPHYRITIC BASALT or ANDESITE showing typical appearance.



RKS-46-08 201 08045_19m.jpg/PPL+R+O/FOV = 0.96 x 1.40 mm/WCF ALTERED PORPHYRITITC BASALT or ANDESITE showing typical closeup appearance of obliquely illuminated fine grained K-feldspar (yellow).



SAMPLE #	**RKS-46-08 202**
ROCK NAME	ALTERED PORPHYRITIC ANDESITE -- probably formed by alteration (secondary K-feldspar + opaques + leucoxene + weakly ferroan calcite + chlorite + quartz) of a porphyritic andesite flow.
MINERALS	Plagioclase (51%) + K-feldspar (20%) + opaques (10%) + leucoxene (8%) + weakly ferroan calcite (5%) + chlorite (5%) + quartz (2%).
TEXTURES	Phaneritic, holocrystalline, porphyritic, medium grained, non-directed fabric. Phenocrysts (15%) subhedral to euhedral, whole, isolated to glomeroporphyritic, 1200-3600 µm. Plagioclase (15%) weakly altered to weakly ferroan calcite + opaques. Groundmass (85%) has an intergranular texture and is composed of [plagioclase moderately altered to K-feldspar] + [opaques moderately altered to leucoxene. Vesicles (0%) and Xenoliths (0%) were not observed.
ALTERATION	Mineralized by quartz + weakly ferroan calcite + opaques.
SECTIONING	Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA
PHOTOS	Refer to next page.

RKS-46-08 202 08045_20m.jpg/XPL/FOV = 4.00 x 5.83 mm/WCF ALTERED PORPHYRITIC ANDESITE showing typical appearance.

SAMPLE # **RKS-47-08 201**

ROCK NAME ALTERED SILICIC VOLCANIC ROCK -- probably formed by hydrothermal alteration (secondary leucoxene + weakly ferroan calcite + chlorite + quartz + opaques) of a aphyric trachyte dike (?).

MINERALS Microcrystalline [K-feldspar + plagioclase] (78%) + leucoxene (10%) + weakly ferroan calcite (7%) + chlorite (3%) + quartz (2%) + opaques (<1%).

TEXTURES Aphanitic, holocrystalline, aphyric, very fine grained, non-directed fabric.

Phenocrysts (0%) are absent.

Groundmass (100%) is composed of finely intergrown anhedral [K-feldspar + plagioclase].

Vesicles (0%) and Xenoliths (0%) were not observed.

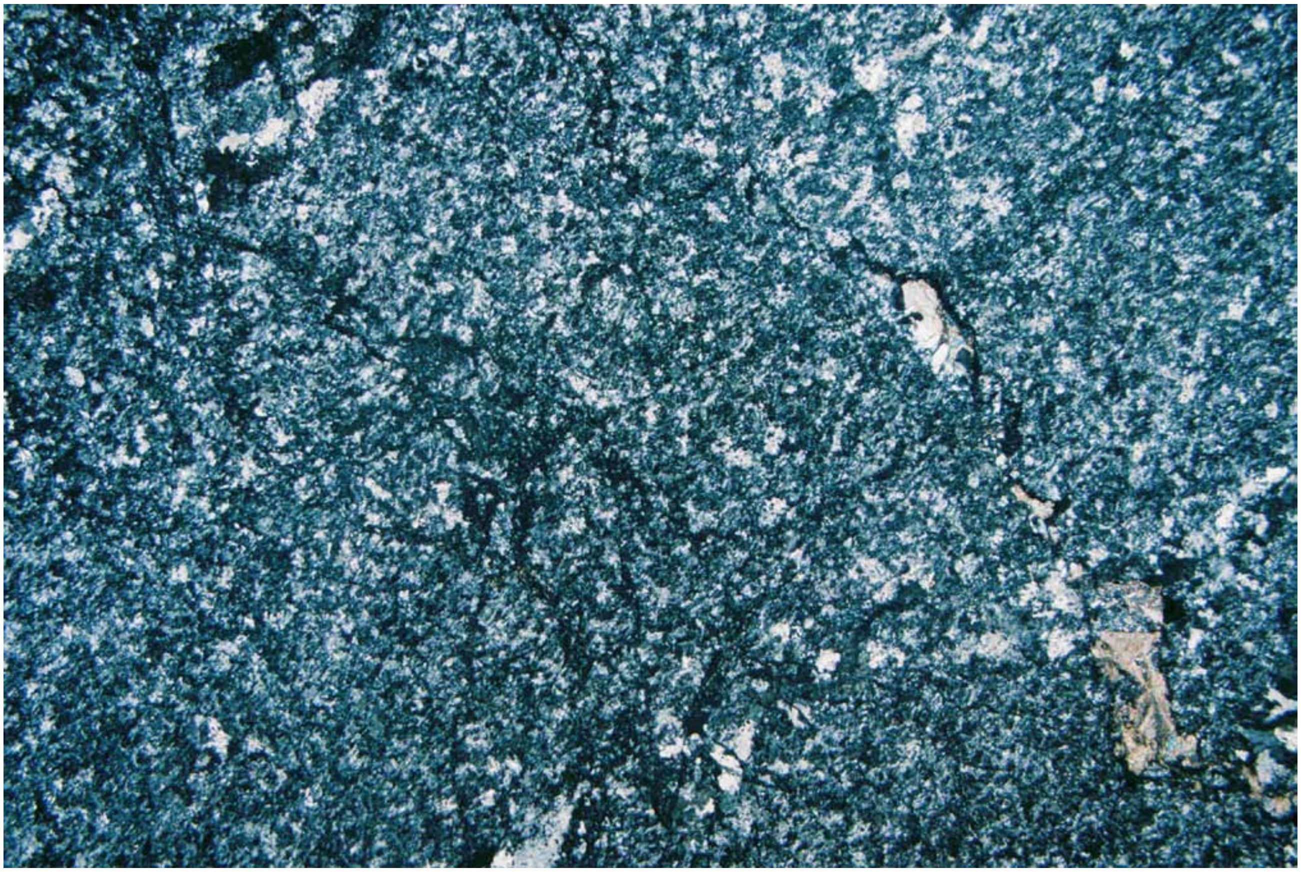
ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) veins of quartz + weakly ferroan dolomite + chlorite + opaques; structures mineralized by weakly ferroan calcite.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA

PHOTOS Refer to next two (2) pages.

RKS-47-08 201 08045_22m.jpg/XPL/FOV = 4.00 x 5.83 mm/WCF ALTERED SILICIC VOLCANIC ROCK showing typical appearance of fine aphyric texture structures mineralized by weakly ferroan calcite.

RKS-47-08 201 08045_21m.jpg/XPL/FOV = 4.00 x 5.83 mm/WCF ALTERED SILICIC VOLCANIC ROCK showing typical appearance of fine aphyric texture.



SAMPLE # **MRE-SI4A**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + opaques + prehnite + chlorite + clay) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (45%) + quartz (25%) + plagioclase (25%) + opaques (2%) + prehnite (1%) + chlorite (1%) + clay (1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1-4 mm, angular to subangular. Contacts between framework components are floating to tangential.

Phenocryst Fragments (35%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (25%) + quartz (10%)].

Lithic Fragments (15%) are composed of basalt and dacite

Pumice Fragments (0%) were not observed.

Matrix/Cement (50%) is composed of moderately welded K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass; and (2) plagioclase weakly altered to prehnite + clay.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

MRE-SI4A 07044/10/DAY/3X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.

MRE-SI4A 07051/14/PPL/28X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of moderately welded devitrified glass shards.

SAMPLE # **MRE-SI4B**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + chlorite + ferroan calcite + opaques) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (38%) + quartz (25%) + plagioclase (25%) + chlorite (5%) + ferroan calcite (5%) + opaques (2%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

<u>Framework Components (50%)</u> are 1-15 mm, angular to subangular. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (25%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (15%) + quartz (10%)].
>
> **Lithic Fragments (25%)** are composed of basalt and dacite.
>
> **Pumice Fragments (0%)** were not observed.

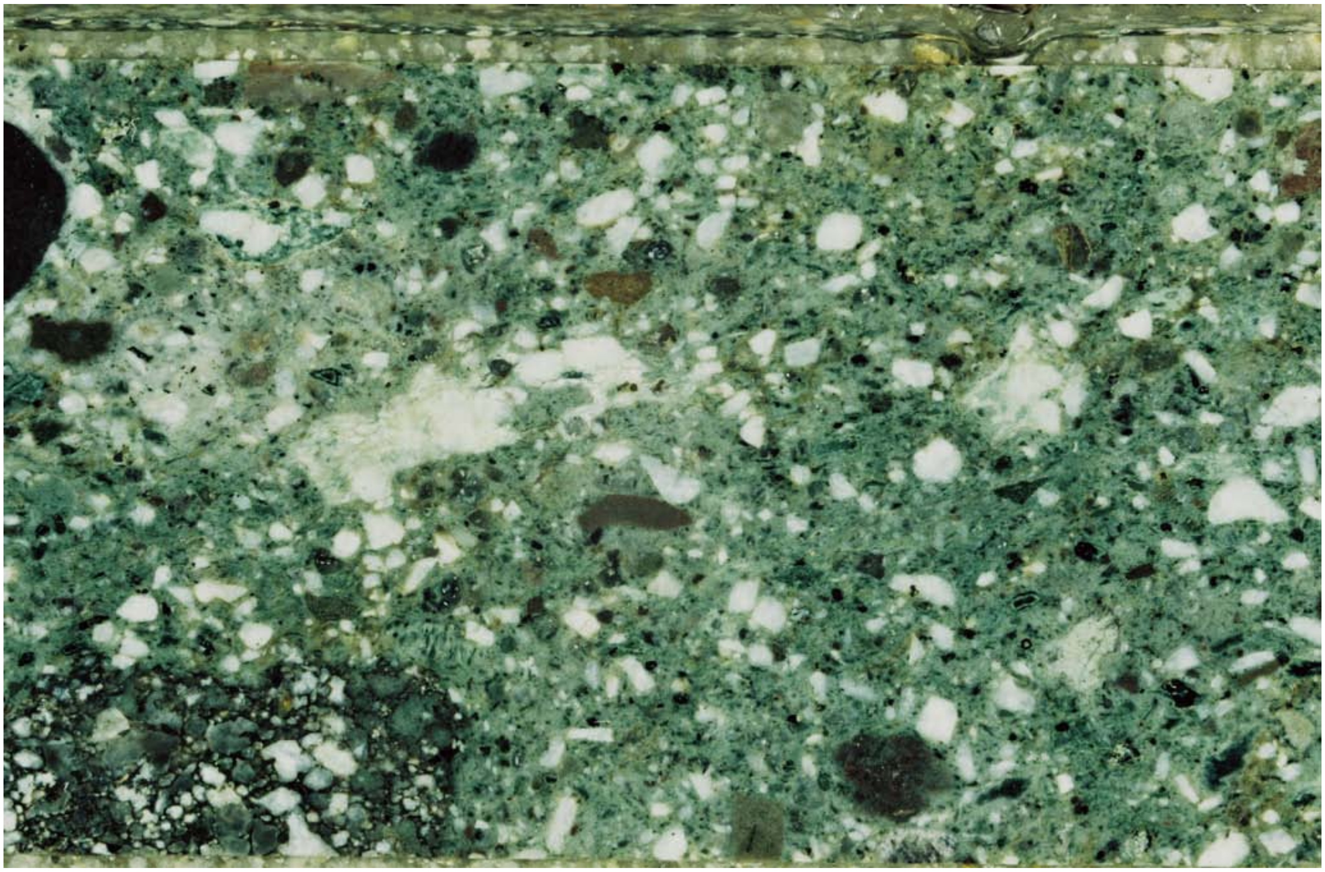
<u>Matrix/Cement (50%)</u> is composed of moderately welded K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass; and (2) plagioclase weakly altered to ferroan calcite + clay.

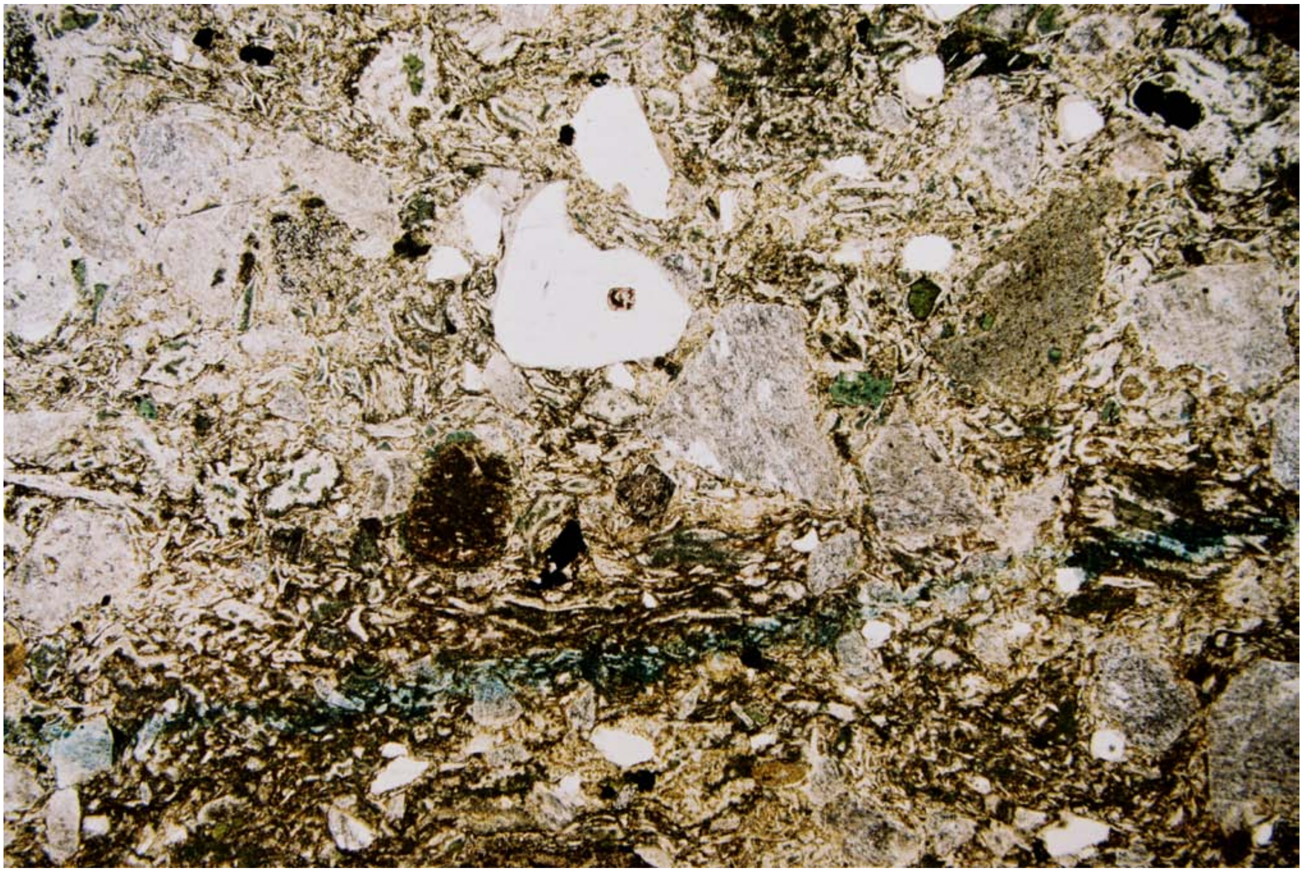
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

MRE-SI4B 07044/11/DAY/3X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



MRE-SI4B 07051/15/PPL/28X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of moderately welded devitrified glass shards.



SAMPLE # **MRE-SI4C**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + chlorite + opaques + ferroan calcite) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (37%) + plagioclase (30%) + quartz (25%) + chlorite (3%) + opaques (2%) + ferroan calcite (<1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Moderate welding has produced a moderately directed fabric.

Framework Components (50%) are 1-14 mm, angular to subangular. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (30%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (20%) + quartz (10%)].
>
> **Lithic Fragments (20%)** are composed of basalt and dacite
>
> **Pumice Fragments (0%)** were not observed.

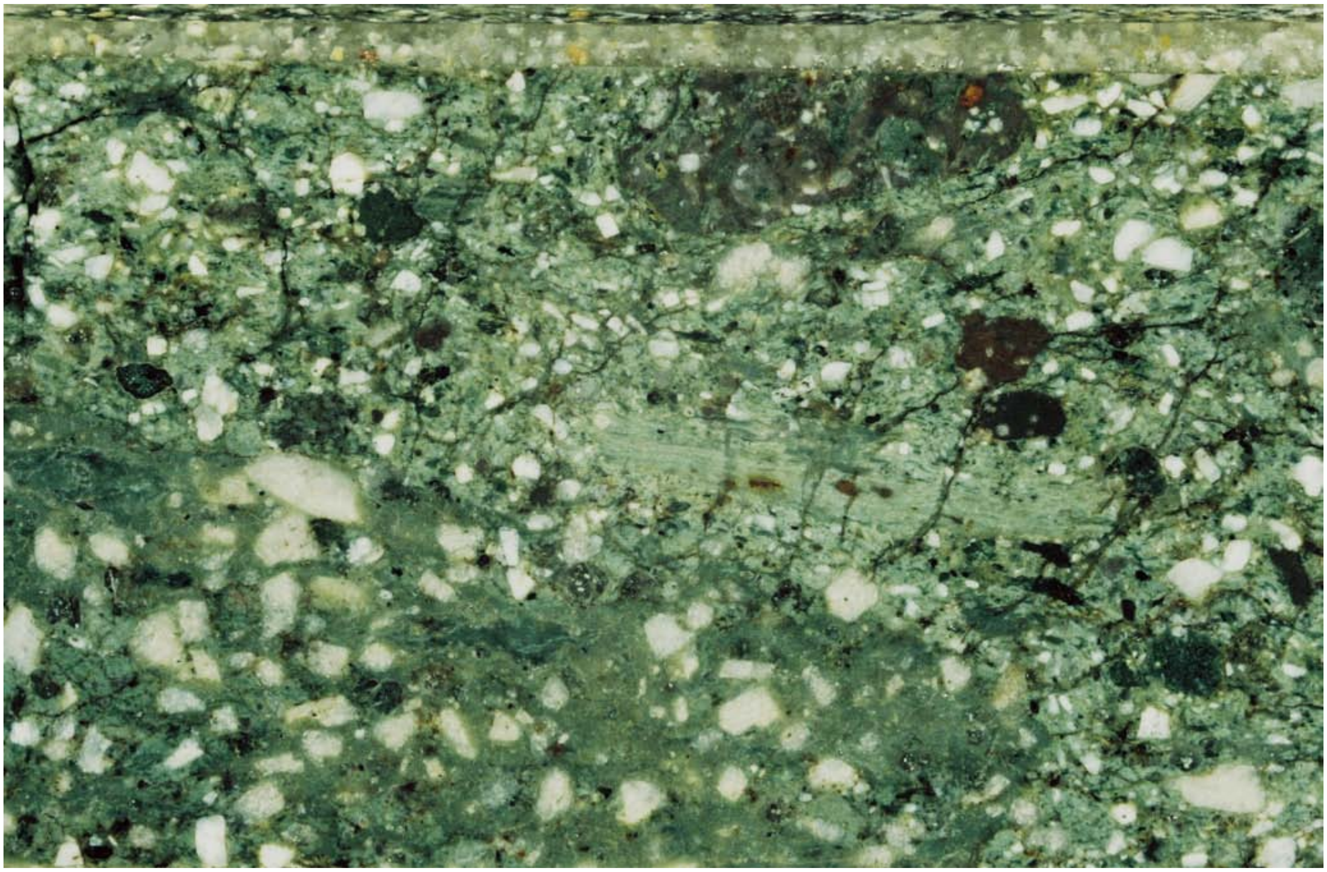
Matrix/Cement (50%) is composed of moderately welded devitrified K-glass.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass; and (2) plagioclase weakly altered to clay.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

MRE-SI4C 07044/12/DAY/3X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



MRE-SI4C 07051/16/PPL/28X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of moderately welded devitrified glass shards.

SAMPLE # **MRE-05-08 201**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + scapolite + prehnite + chlorite + FEOH) of an unwelded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline K-glass (45%) + plagioclase (32%) + quartz (10%) + scapolite (5%) + opaques (3%) + prehnite (2%) + chlorite (2%) + FEOH (1%).

TEXTURES Pyroclastic, partially devitrified hypocrystalline. Framework Components (50%) are angular, 800-4400 :m. Contacts between framework components are floating to tangential.

Phenocryst Fragments (30%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (22%) + quartz (8%)].

Lithic Fragments (20%) are dominated by basalt or andesite with minor dacite.

Pumice Fragments (0%) were not observed.

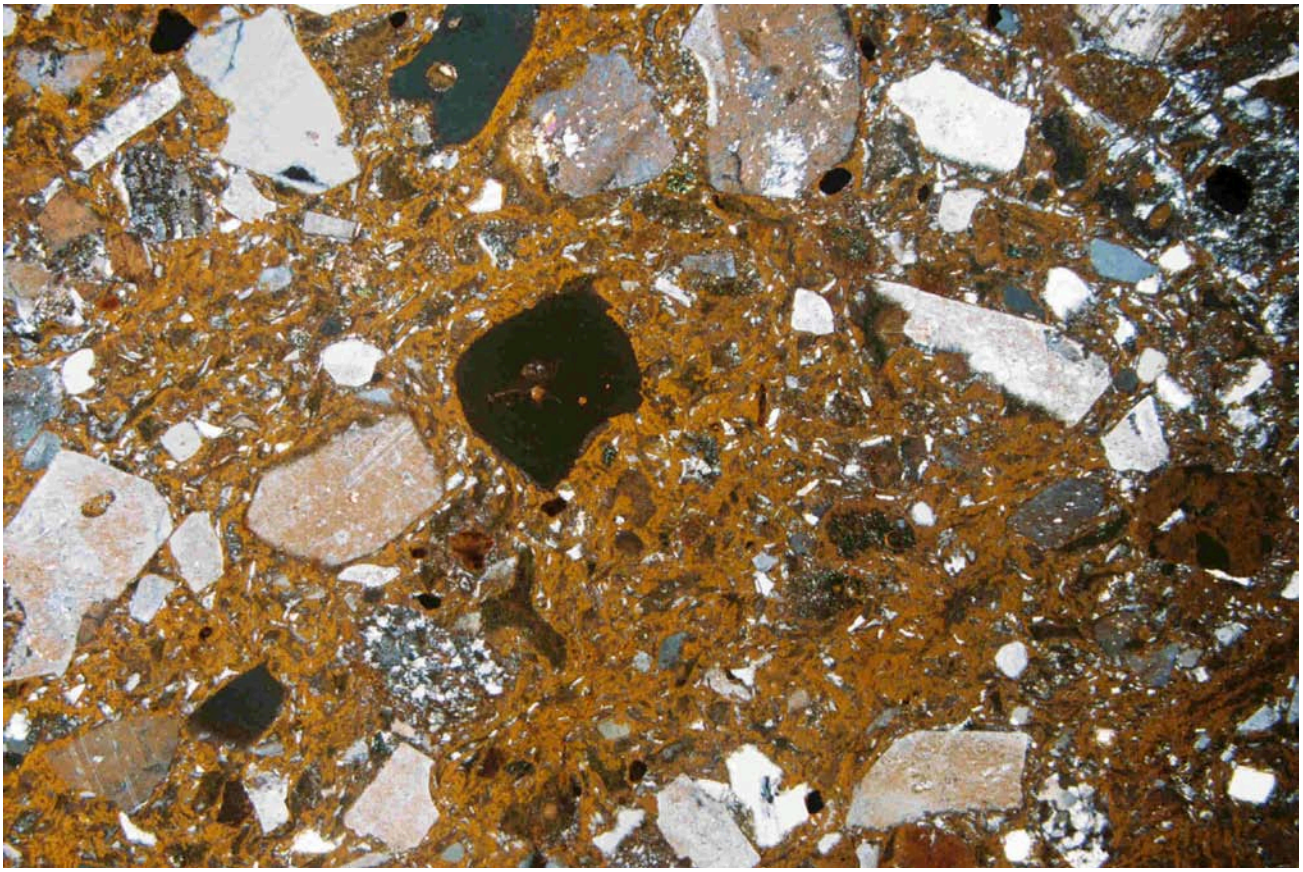
Matrix/Cement (50%) is composed of weakly welded K-glass devitrified to quartz + indeterminate cryptocrystalline material.

ALTERATION The following alteration features are present but of indeterminate relative ages: (1) K-glass devitrified to quartz + indeterminate cryptocrystalline material; and (2) plagioclase moderately altered to scapolite + prehnite ± chlorite.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA

PHOTOS Refer to next page.

MRE-05-08 201 08045_07m.jpg/PPL+R+O/FOV = 4.00 x 5.83 mm/WCF ALTERED DACITE ASH-FLOW TUFF showing typical appearance. Oblique reflected light makes the devitrified K-glass appear brownish orange in this view.



SAMPLE # **MRE-SI5A**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay (sericite ?) + ferroan calcite + chlorite + opaques) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (53%) + plagioclase (15%) + quartz (15%) + clay (sericite ?) (10%) + ferroan calcite (3%) + chlorite (2%) + opaques (2%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1-26 mm, angular to subangular. Contacts between framework components are floating to tangential.

Phenocryst Fragments (30%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (20%) + quartz (10%)].

Lithic Fragments (18%) are composed of basalt and dacite

Pumice Fragments (2%) are composed of dacite porphyry.

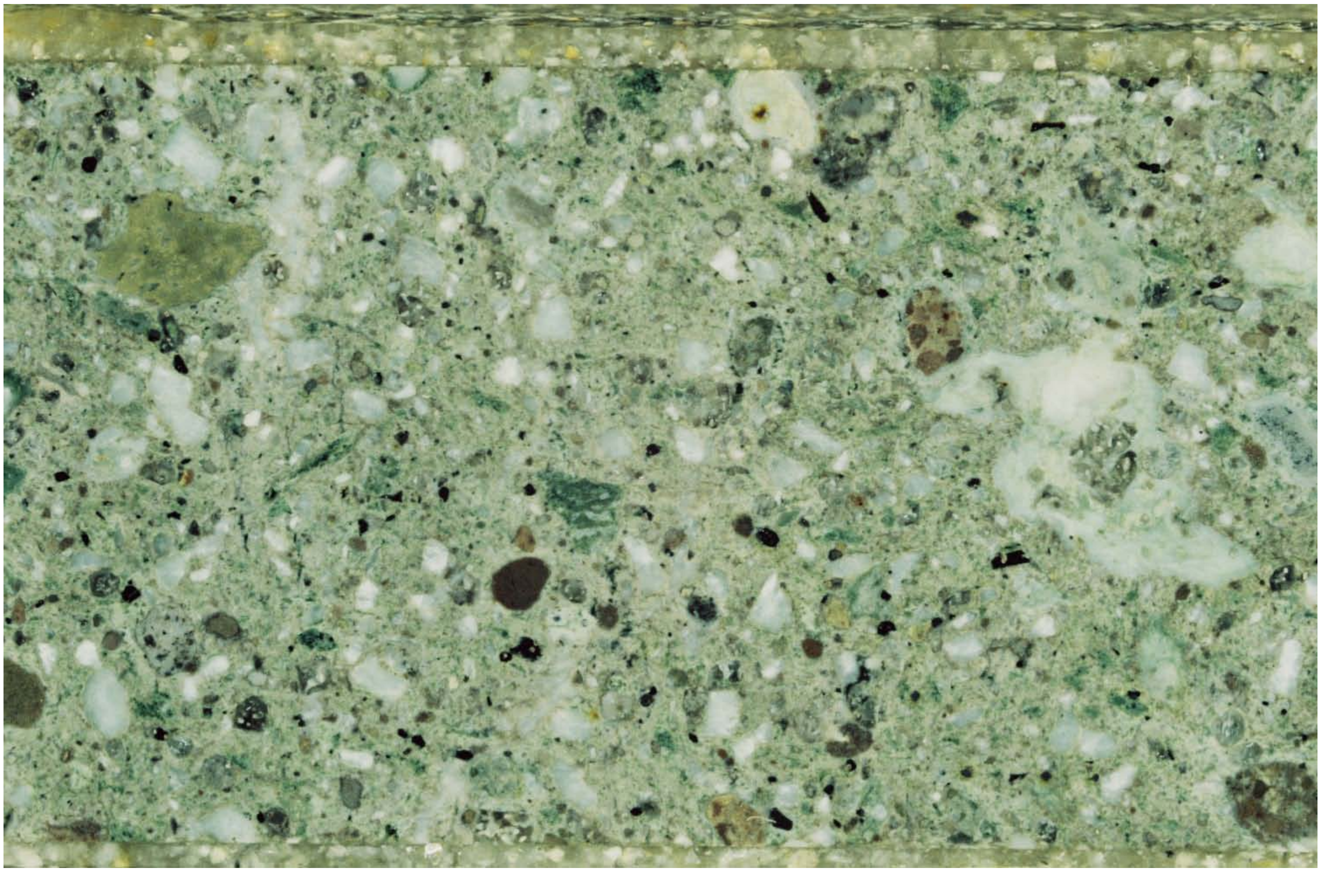
Matrix/Cement (50%) is composed of moderately welded K-glass moderately devitrified to quartz ± ferroan calcite.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) devitrified K-glass (2) plagioclase weakly altered to clay; and (3) veins of quartz + clay.

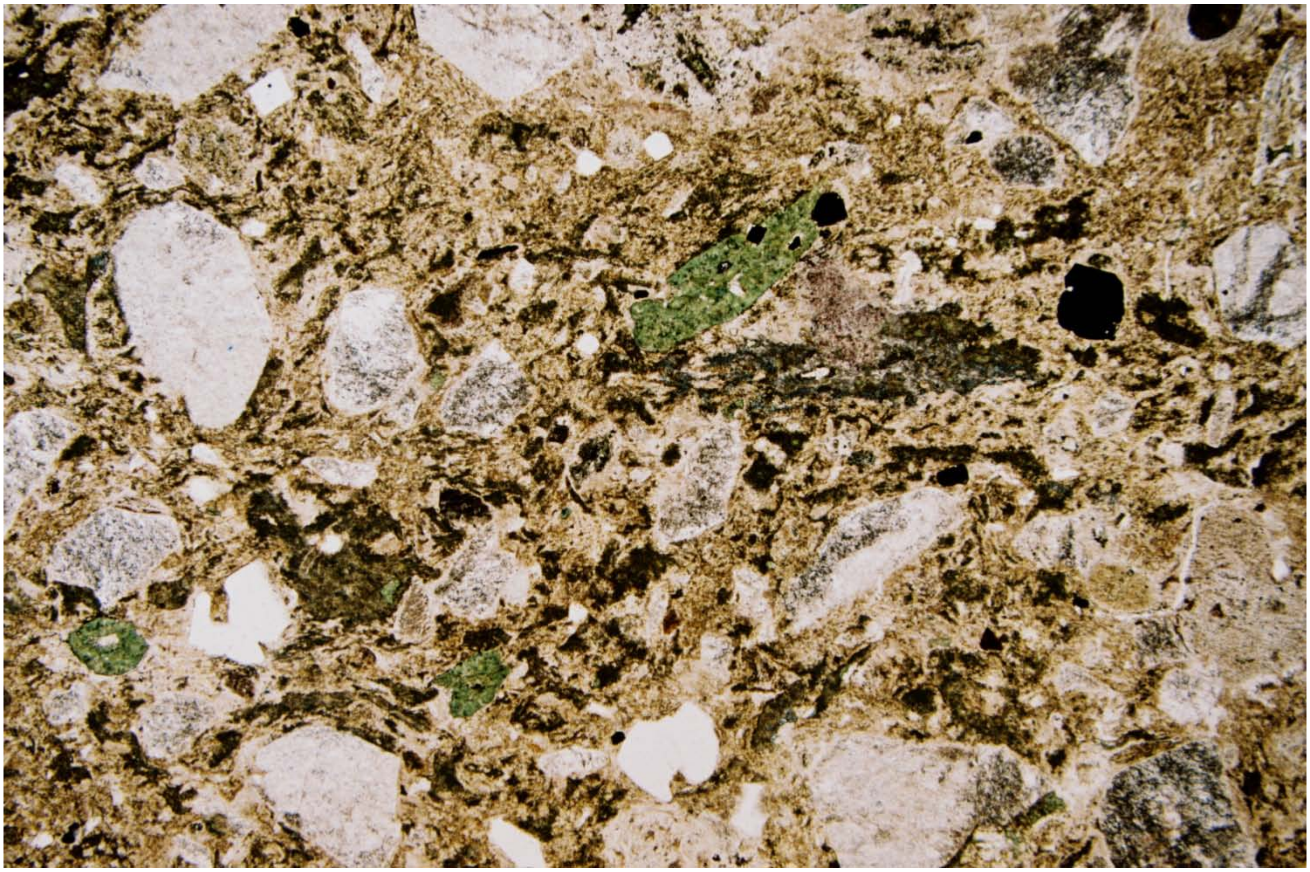
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

MRE-SI5A 07044/13/DAY/3X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



MRE-SI5A 07051/17/PPL/28X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of moderately welded devitrified glass shards.



SAMPLE # **MRE-SI5B**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay (sericite ?) + chlorite + opaques + clinozoisite) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (38%) + plagioclase (25%) + quartz (25%) + clay (sericite ?) (5%) + chlorite (3%) + opaques (2%) + clinozoisite (2%) + prehnite (<1%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (45%) are 1-8 mm, angular to subangular. Contacts between framework components are floating to tangential.

Phenocryst Fragments (30%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (20%) + quartz (10%)].

Lithic Fragments (15%) are composed of basalt and dacite

Pumice Fragments (0%) were not observed.

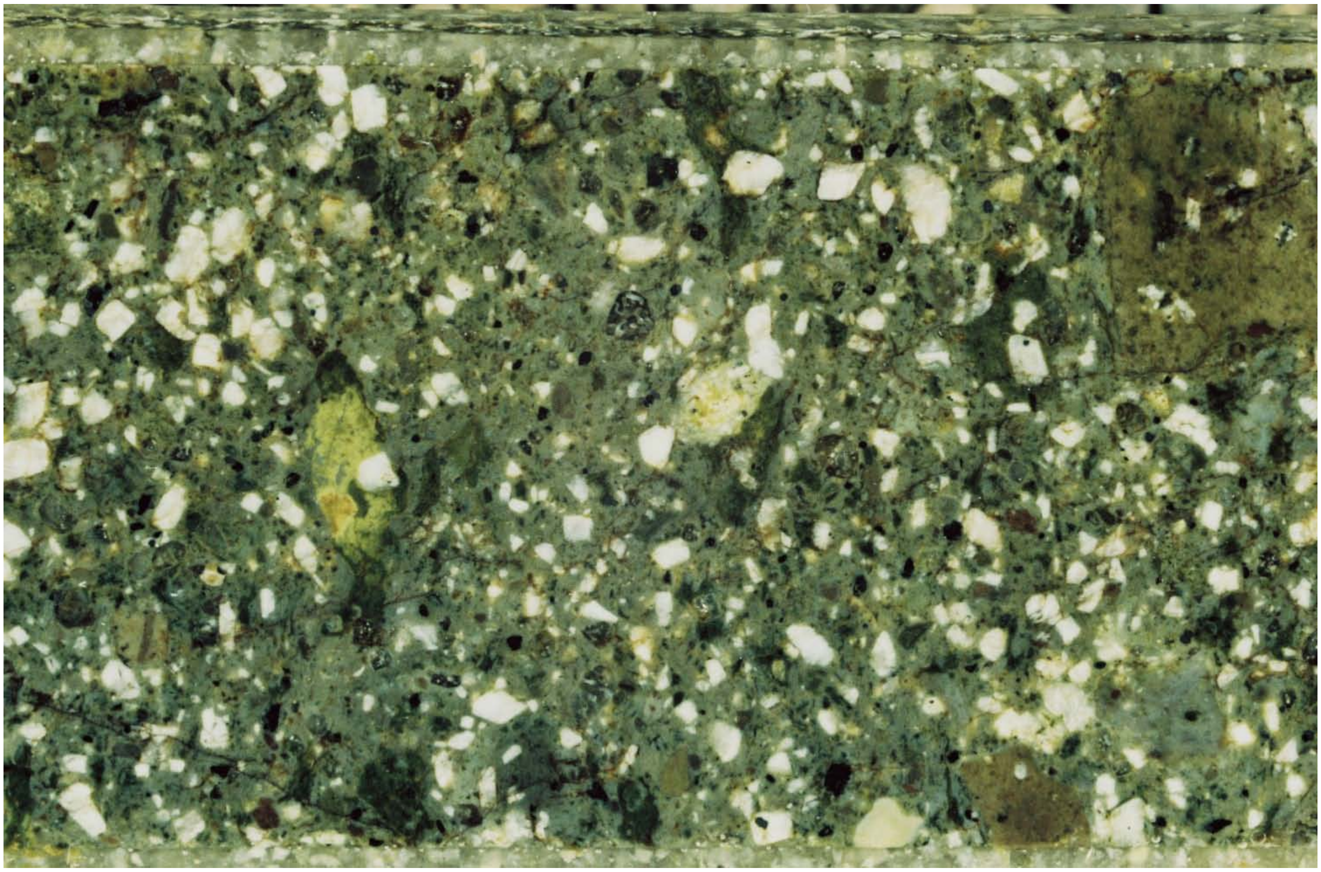
Matrix/Cement (55%) is composed of moderately welded K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) Devitrified K-glass moderately to quartz; and (2) plagioclase weakly altered to clay + clinozoisite ± prehnite.

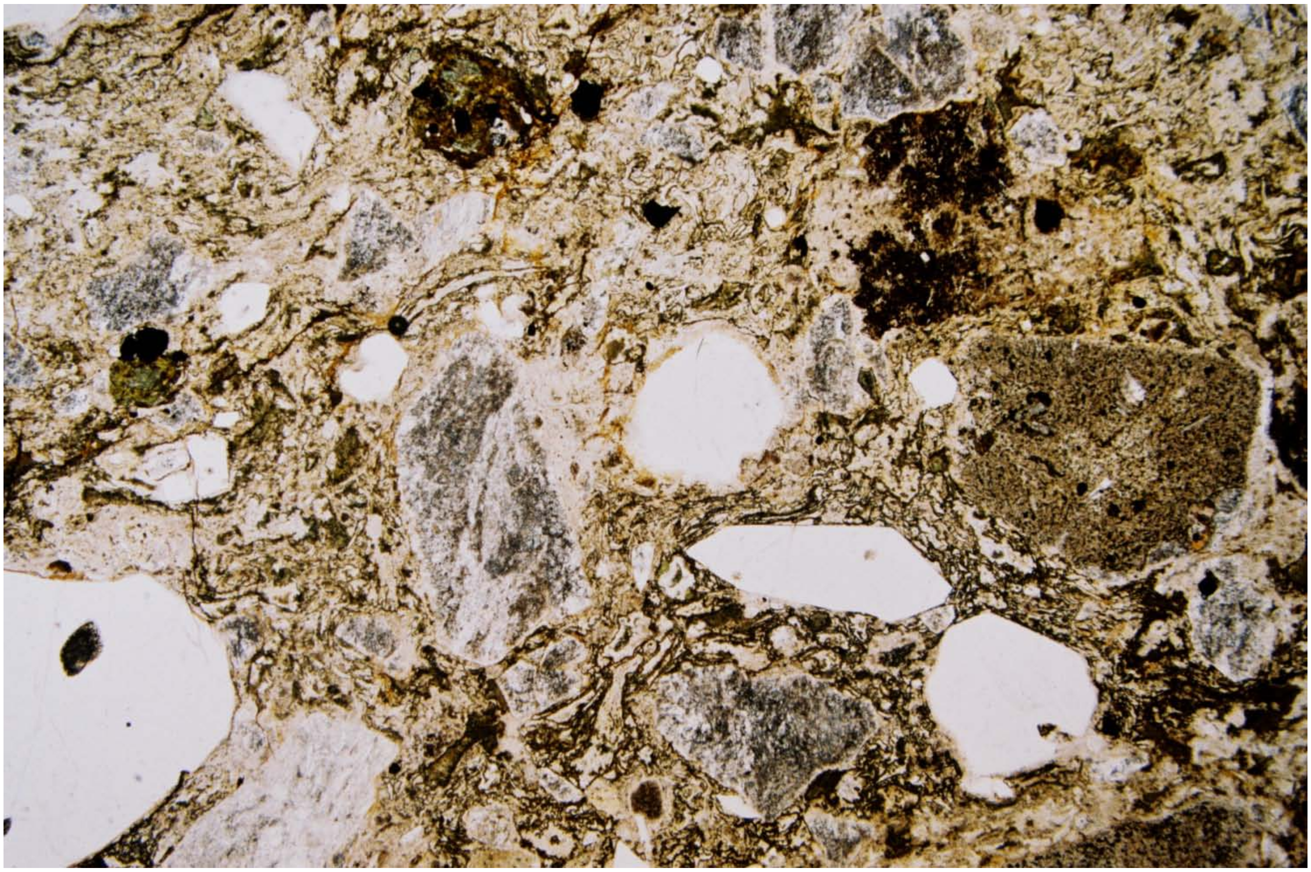
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

MRE-SI5B 07044/14/DAY/3X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



\MRE-SI5B 07051/18/PPL/28X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of moderately welded devitrified glass shards.



SAMPLE # **MRE-SI5C**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + clay + chlorite + opaques + clinozoisite) of a welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (30%) + plagioclase (28%) + quartz (25%) + clay (5%) + chlorite (3%) + opaques (2%) + clinozoisite (2%) + FEOH (2%).

TEXTURES Pyroclastic, devitrified hypocrystalline. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are 1-4 mm, angular to subangular. Contacts between framework components are floating to tangential.

Phenocryst Fragments (35%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (25%) + quartz (10%)].

Lithic Fragments (15%) are composed of basalt and dacite

Pumice Fragments (0%) were not observed.

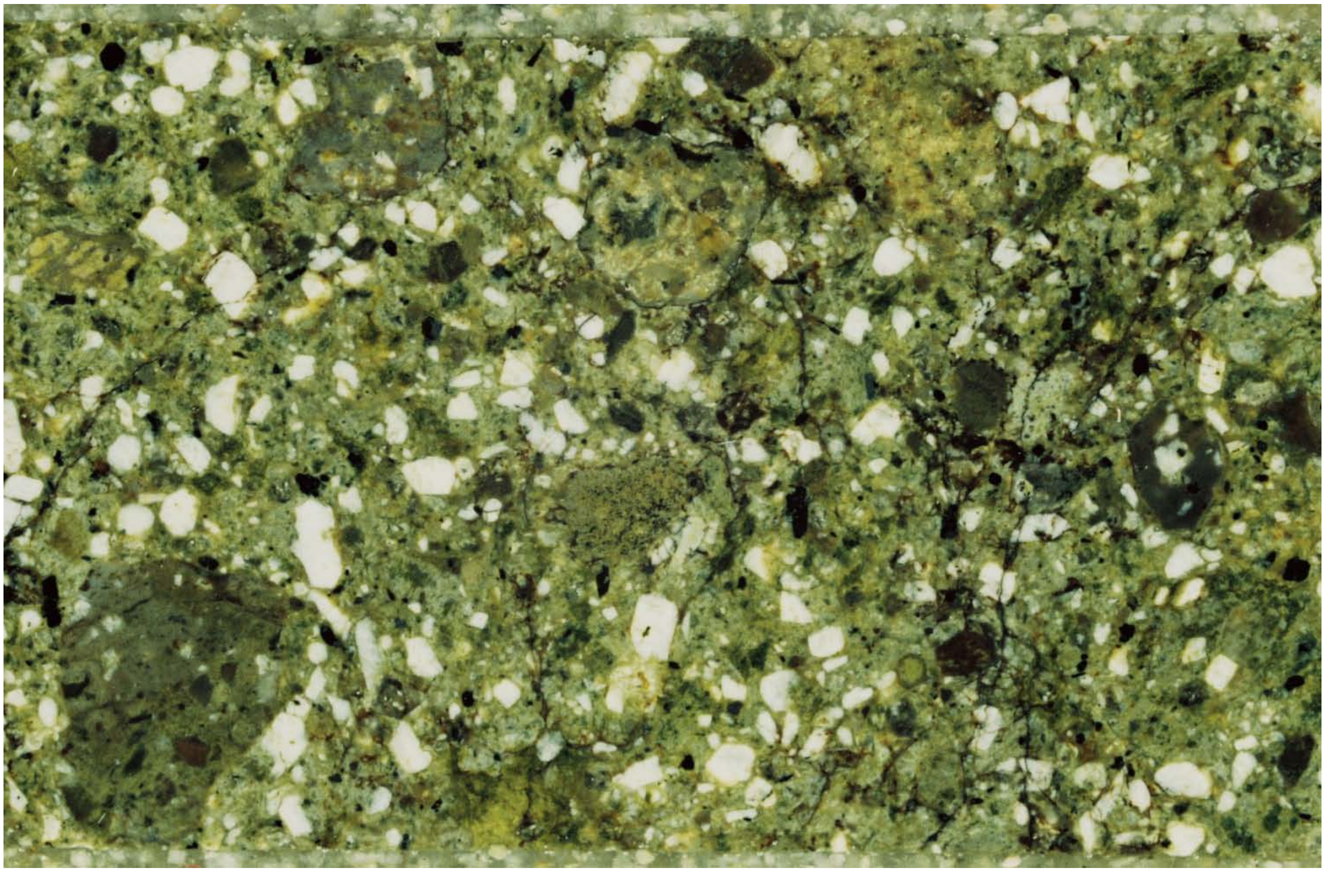
Matrix/Cement (50%) is composed of moderately welded K-glass moderately devitrified to quartz.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1)Devitrified K-glass; (2) plagioclase weakly altered to clay + clinozoisite ± prehnite; (3) veinlets of quartz; and (4) veinlets of FEOH.

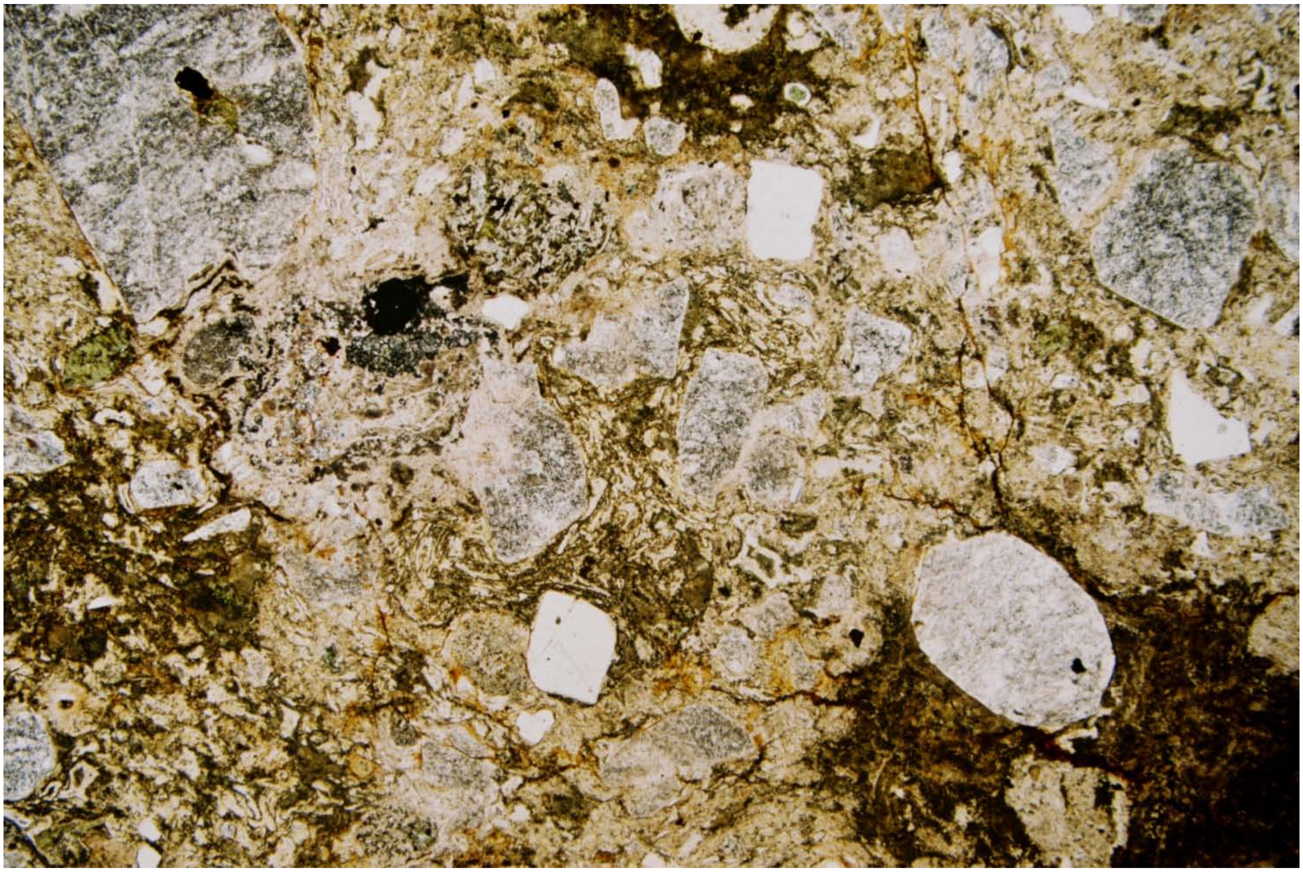
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOGRAPHS Refer to next two (2) pages.

MRE-SI5C 07044/15/DAY/3X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of hand specimen.



MRE-SI5C 07051/19/PPL/28X/UNN ALTERED DACITE ASH-FLOW TUFF showing typical appearance of phenocrysts and lithic fragments in a groundmass of moderately welded devitrified glass shards.



SAMPLE # **MRE-06-08 201**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + scapolite + chlorite + prehnite + FEOH) of a moderately welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (50%) + plagioclase (32%) + quartz (7%) + scapolite (4%) + opaques (2%) + chlorite (2%) + prehnite (1%) + FEOH (<1%).

TEXTURES Pyroclastic, partially devitrified hypocrystalline. Moderate welding has produced a weakly directed fabric. Framework Components (45%) are angular, 880-7200 :m. Contacts between framework components are floating to tangential.

Phenocryst Fragments (30%) are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (25%) + quartz (5%)].

Lithic Fragments (15%) are dominated by basalt and andesite with minor dacite.

Pumice Fragments (0%) were not observed.

Matrix/Cement (55%) is composed of weakly welded K-glass devitrified to quartz + indeterminate cryptocrystalline material.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) weak welding; (2) K-glass devitrified to quartz + indeterminate cryptocrystalline material; and (3) plagioclase moderately altered to scapolite ± prehnite ± chlorite.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA

PHOTOS Refer to next page.

MRE-06-08 201 08045_08m.jpg/PPL/FOV = 4.00 x 5.83 mm/WCF ALTERED DACITE ASH-FLOW TUFF showing typical appearance.

SAMPLE # **MRE-07-08 201**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + scapolite + prehnite + chlorite + FEOH) of a moderately welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (55%) + plagioclase (26%) + quartz (9%) + scapolite (3%) + opaques (3%) + prehnite (2%) + chlorite (2%) + FEOH (1%).

TEXTURES Pyroclastic, devitrified hypocrystalline glassy flow textures. Moderate welding has produced a weakly directed fabric.

Framework Components (45%) are angular, 800-15,000 :m. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (25%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (18%) + quartz (7%)].
>
> **Lithic Fragments (10%)** are dominated by various basalt or andesite with minor dacite and siltstone.
>
> **Pumice Fragments (10%)** are composed of sparsely porphyritic dacite glass.

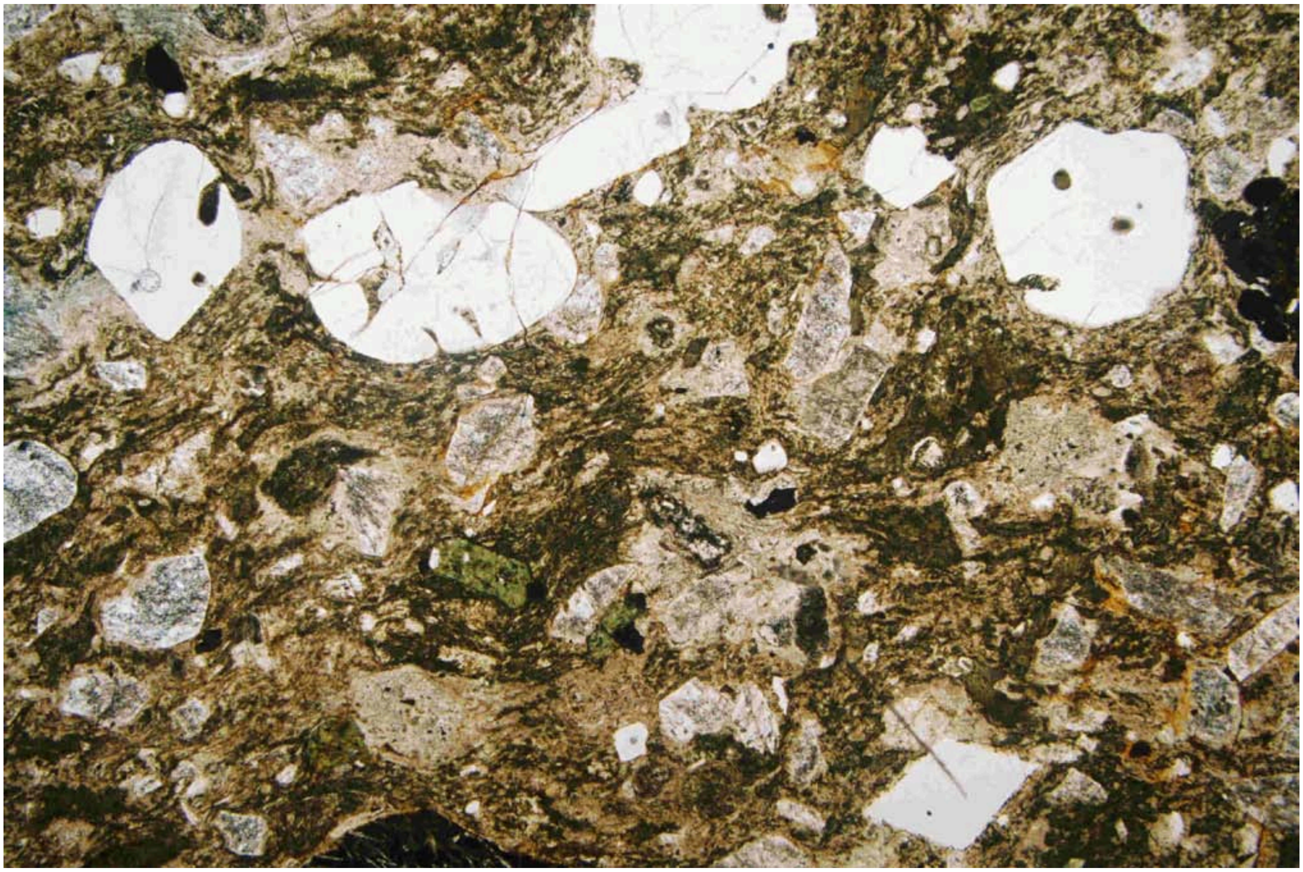
Matrix/Cement (55%) is composed of weakly welded K-glass devitrified to quartz + indeterminate cryptocrystalline material.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) K-glass devitrified to quartz + indeterminate cryptocrystalline material; (2) plagioclase moderately altered to scapolite ± prehnite ± chlorite; (3) veins of quartz; and (4) veinlets of FEOH.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA

PHOTOS Refer to next page.

MRE-07-08 201 08045_09m.jpg/PPL/FOV = 4.00 x 5.83 mm/WCF ALTERED DACITE ASH-FLOW TUFF showing typical appearance.



SAMPLE # **MRE-07-08 202**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + sericite + calcite + chlorite + FEOH) of a moderately welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (50%) + plagioclase (26%) + quartz (10%) + sericite (5%) + calcite (5%) + chlorite (2%) + opaques (2%) + FEOH (<1%).

TEXTURES Pyroclastic, devitrified hypocrystalline glassy flow textures. Moderate welding has produced a weakly directed fabric.

Framework Components (50%) are angular, 800-6200 :m. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (30%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (20%) + quartz (10%)].
>
> **Lithic Fragments (10%)** are dominated by basalt or andesite with minor dacite.
>
> **Pumice Fragments (10%)** are composed of sparsely porphyritic devitrified dacite glass.

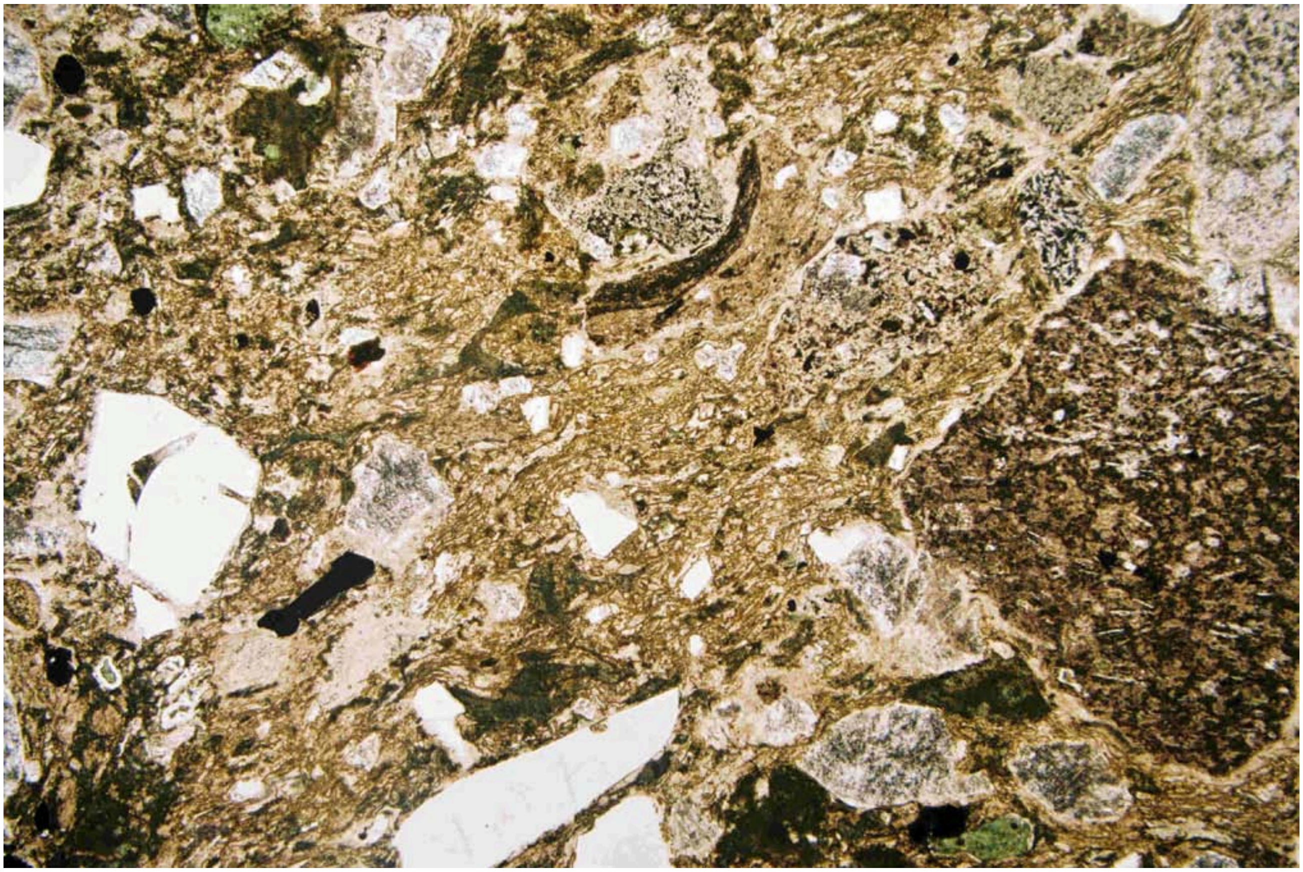
Matrix/Cement (50%) is composed of weakly welded K-glass weakly devitrified to quartz + indeterminate cryptocrystalline material.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) K-glass devitrified to quartz + indeterminate cryptocrystalline material; (2) plagioclase moderately altered to sericite + calcite; (3) veins of quartz; and (4) veins of calcite.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA

PHOTOS Refer to next page.

MRE-07-08 202 08045_10m.jpg/PPL/FOV = 4.00 x 5.83 mm/WCF ALTERED DACITE ASH-FLOW TUFF showing typical appearance.



SAMPLE # **MRE-08-08 201**

ROCK NAME ALTERED DACITE ASH-FLOW TUFF -- probably formed by devitrification and alteration (secondary quartz + scapolite + chlorite + prehnite + FEOH) of a weakly welded dacite ash-flow tuff protolith.

MINERALS Cryptocrystalline devitrified K-glass (45%) + plagioclase (32%) + quartz (12%) + scapolite (5%) + opaques (3%) + chlorite (2%) + prehnite (1%) + FEOH (<1%).

TEXTURES Pyroclastic, devitrified hypocrystalline glassy flow texture. Weak welding has produced a weakly directed fabric.

Framework Components (50%) are angular, 800-7400 :m. Contacts between framework components are floating to tangential.

> **Phenocryst Fragments (30%)** are composed of subhedral to euhedral, whole to broken, isolated [plagioclase (21%) + quartz (9%)].
>
> **Lithic Fragments (10%)** are dominated by basalt or andesite with minor dacite.
>
> **Pumice Fragments (10%)** are composed of sparsely porphyritic devitrified dacite glass.

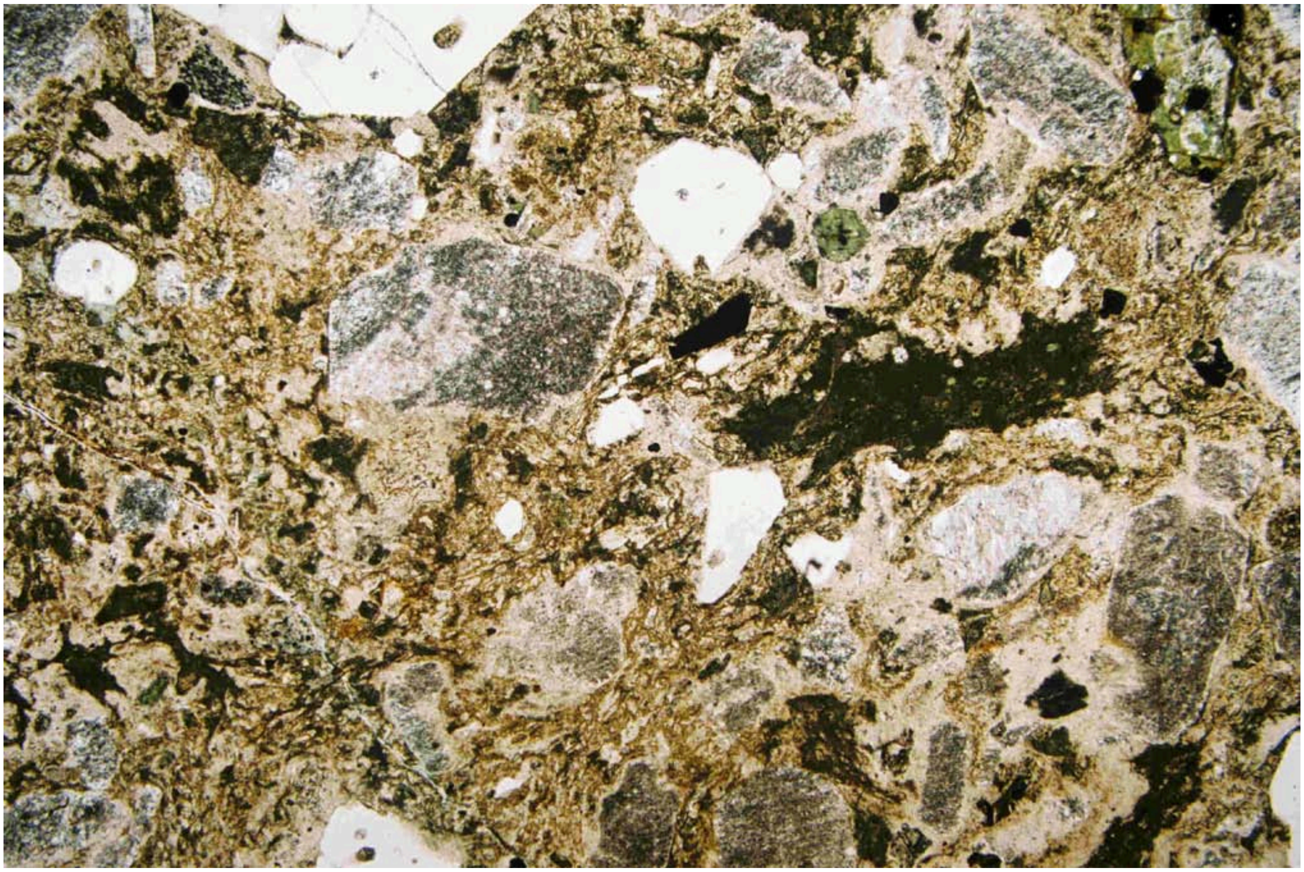
Matrix/Cement (50%) is composed of weakly welded K-glass devitrified to quartz + indeterminate cryptocrystalline material.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) K-glass devitrified to quartz + indeterminate cryptocrystalline material; (2) plagioclase moderately altered to scapolite ± prehnite ± chlorite; and (3) veins of quartz + scapolite + FEOH.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top ½) + [ARS + PF] (right ½) Cover: PLA

PHOTOS Refer to next page.

MRE-08-08 201 08045_11m.jpg/PPL/FOV = 4.00 x 5.83 mm/WCF ALTERED DACITE ASH-FLOW TUFF showing typical appearance.



SAMPLE # **MRE-SI7A**

ROCK NAME HIGHLY ALTERED ANDESITE? -- probably formed by alteration (secondary colorless and green clay (?) + weakly ferroan calcite) of a porphyritic andesite flow. Similar to #7 203.

MINERALS Cryptocrystalline colorless clay (?) groundmass (53%) + plagioclase (20%) + weakly ferroan calcite (12%) + cryptocrystalline green clay (?) groundmass (10%) + opaques (5%).

TEXTURES Phaneritic, holocrystalline, porphyritic, fine grained, non-directed fabric.

Phenocrysts (15%) subhedral to euhedral, whole, isolated to glomeroporphyritic, 600-2200 μm.

Plagioclase (15%) completely altered to weakly ferroan calcite + clay.

Groundmass (85%) has a relict intergranular texture and is composed of [plagioclase strongly altered to cryptocrystalline colorless clay] and [clinopyroxene (?) completely altered to cryptocrystalline green clay].

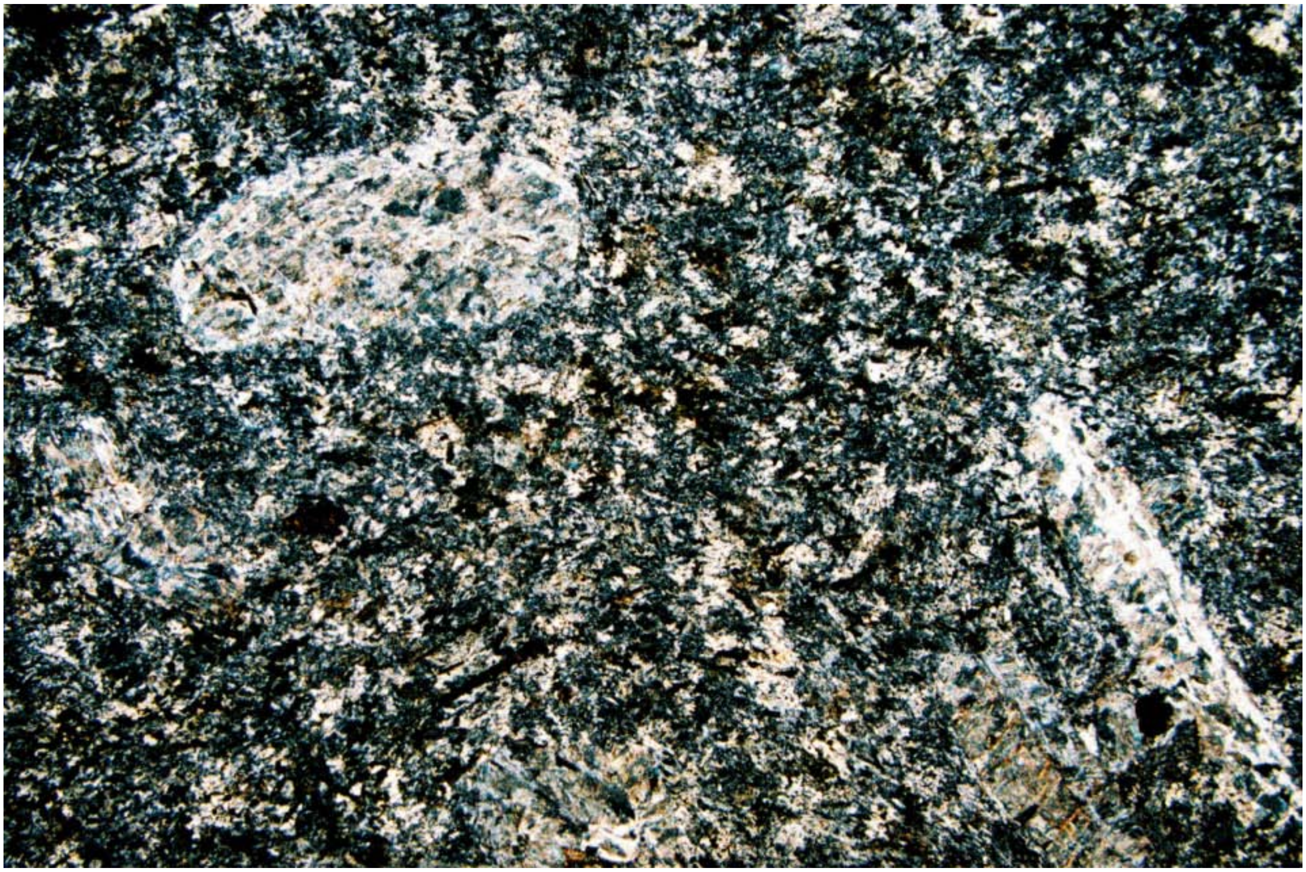
Vesicles (0%) and Xenoliths (0%) were not observed.

ALTERATION No other alteration features were observed.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOS Refer to next page.

MRE-SI7A 08042_06m.jpg/XPL/FOV = 4.00 x 5.83 mm/VZM HIGHLY ALTERED ANDESITE? showing typical appearance.



SAMPLE # **MRE-SI7B**

ROCK NAME ALTERED ANDESITE -- secondary veins indicate hydrothermal brecciation, and hydrothermal alteration (secondary quartz + weakly ferroan calcite + opaques + leucoxene + K-feldspar) of a porphyritic basalt protolith very much like #7 201.

MINERALS Plagioclase (66%) + quartz (12%) + weakly ferroan calcite (10%) + opaques (5%) + leucoxene (5%) + K-feldspar (2%).

TEXTURES Breccia Clasts in veins.

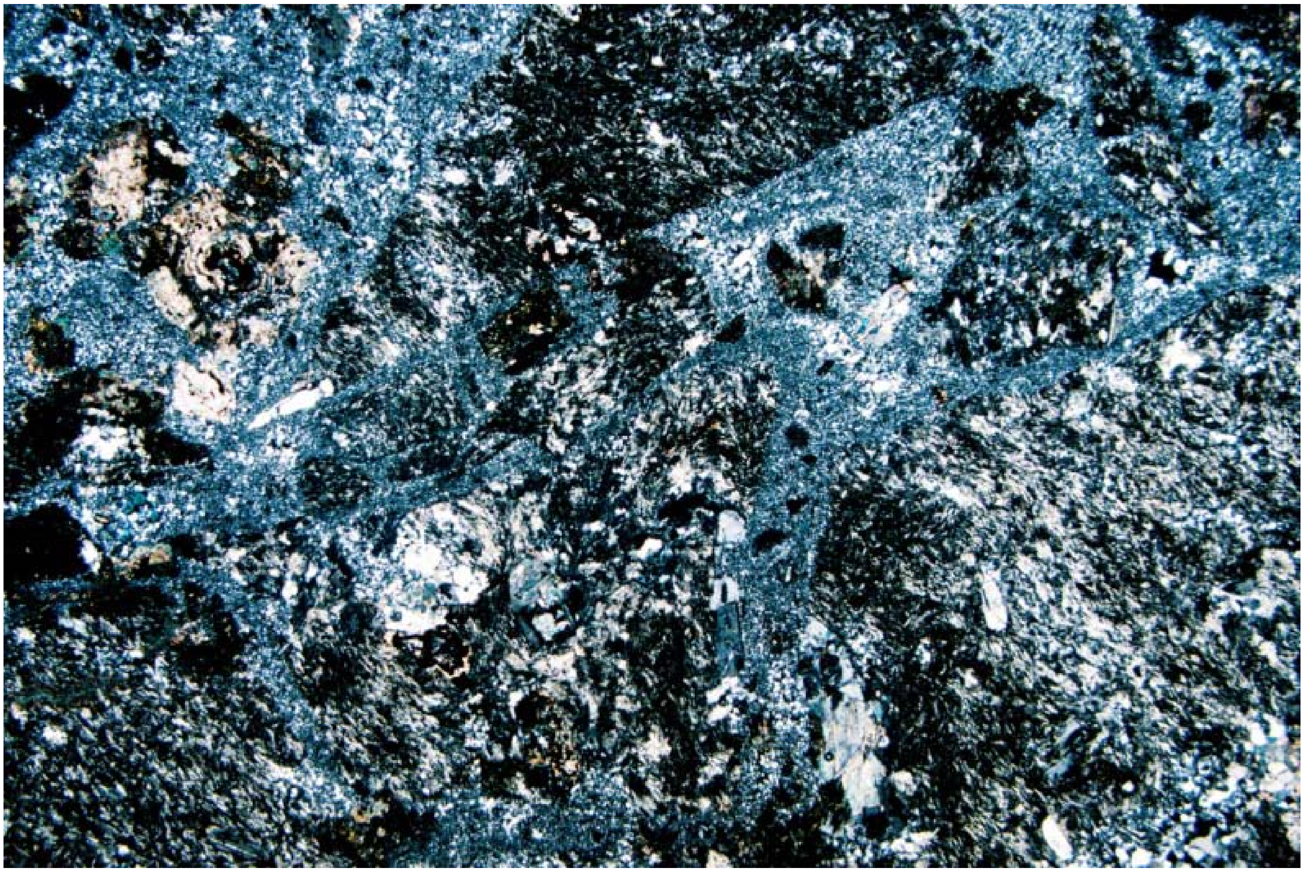
Cement (0%) is composed of cryptocrystalline quartz + weakly ferroan calcite.

ALTERATION Alteration features in relative chronological order from oldest to youngest are: (1) veinlets of K-feldspar; (2) hydrothermal brecciation; (3) cement composed of cryptocrystalline quartz + ferroan calcite; and (4) veinlets of weakly ferroan calcite. The following alteration features are present but of indeterminate relative ages: (1) plagioclase phenocrysts moderately altered to weakly ferroan calcite; and (2) magnetite/ilmenite completely altered to leucoxene.

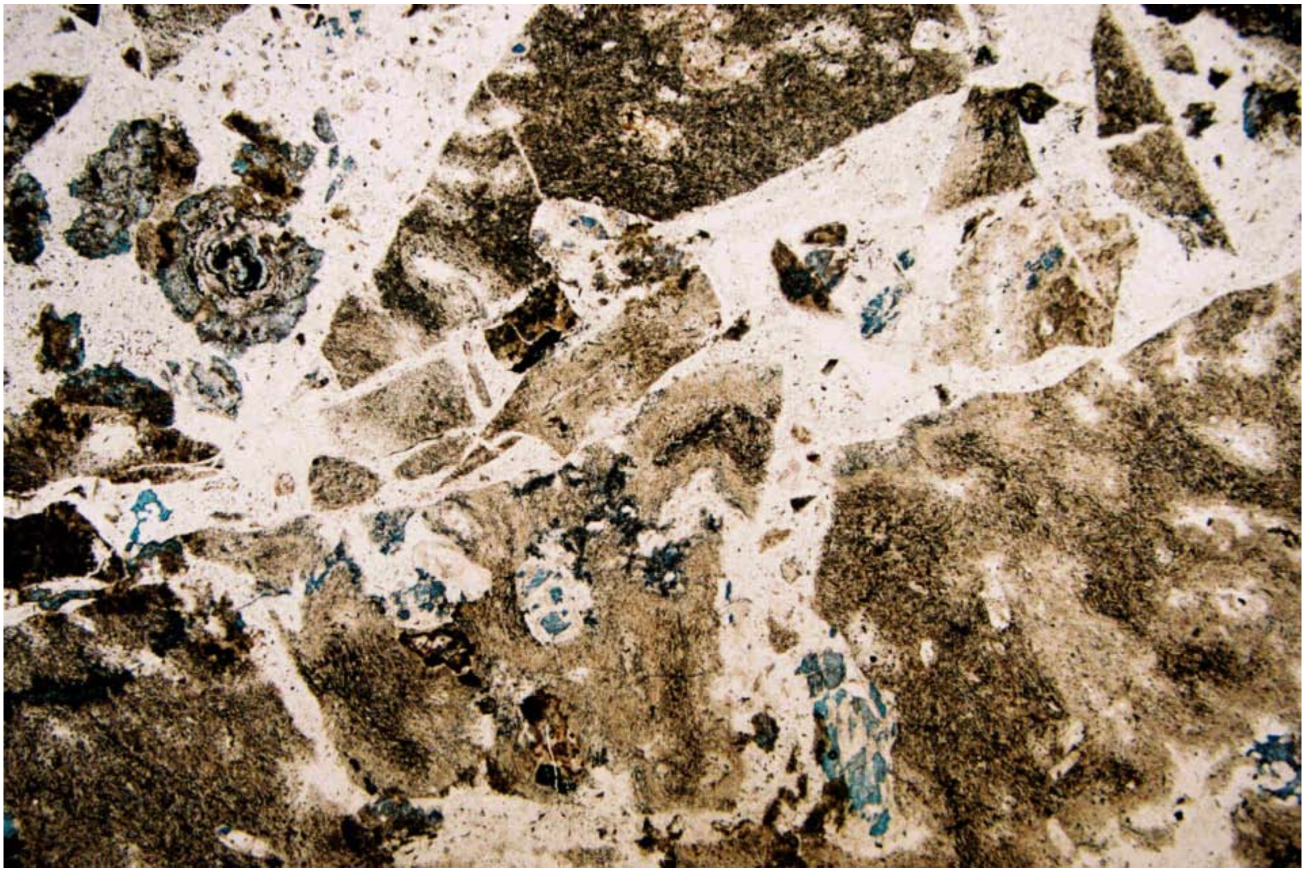
SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOS Refer to next two (2) pages.

MRE-SI7B 08042_07m.jpg/XPL/FOV = 4.00 x 5.83 mm/VZM ALTERED ANDESITE showing typical appearance (same view as 08042/08).



MRE-SI7B 08042_08m.jpg/PPL/FOV = 4.00 x 5.83 mm/VZM ALTERED ANDESITE showing typical appearance (same view as 08042/07).



SAMPLE # **MRE-SI7C**

ROCK NAME HIGHLY ALTERED ANDESITE -- probably formed by alteration (secondary ferroan calcite + cryptocrystalline green clay (?) + opaques + FEOH) of a porphyritic basalt flow like #7 201.

MINERALS Plagioclase (65%) + ferroan calcite (12%) + cryptocrystalline green clay (?) (12%) + opaques (10%) + FEOH (1%).

TEXTURES Phaneritic, holocrystalline, porphyritic, fine grained, non-directed fabric.

Phenocrysts (15%) subhedral to euhedral, whole, isolated to glomeroporphyritic, 880-1600 μm.

Plagioclase (15%) moderately altered to ferroan calcite.

Groundmass (85%) has a relict intergranular texture and is composed of plagioclase + [clinopyroxene (?) completely altered to cryptocrystalline green clay].

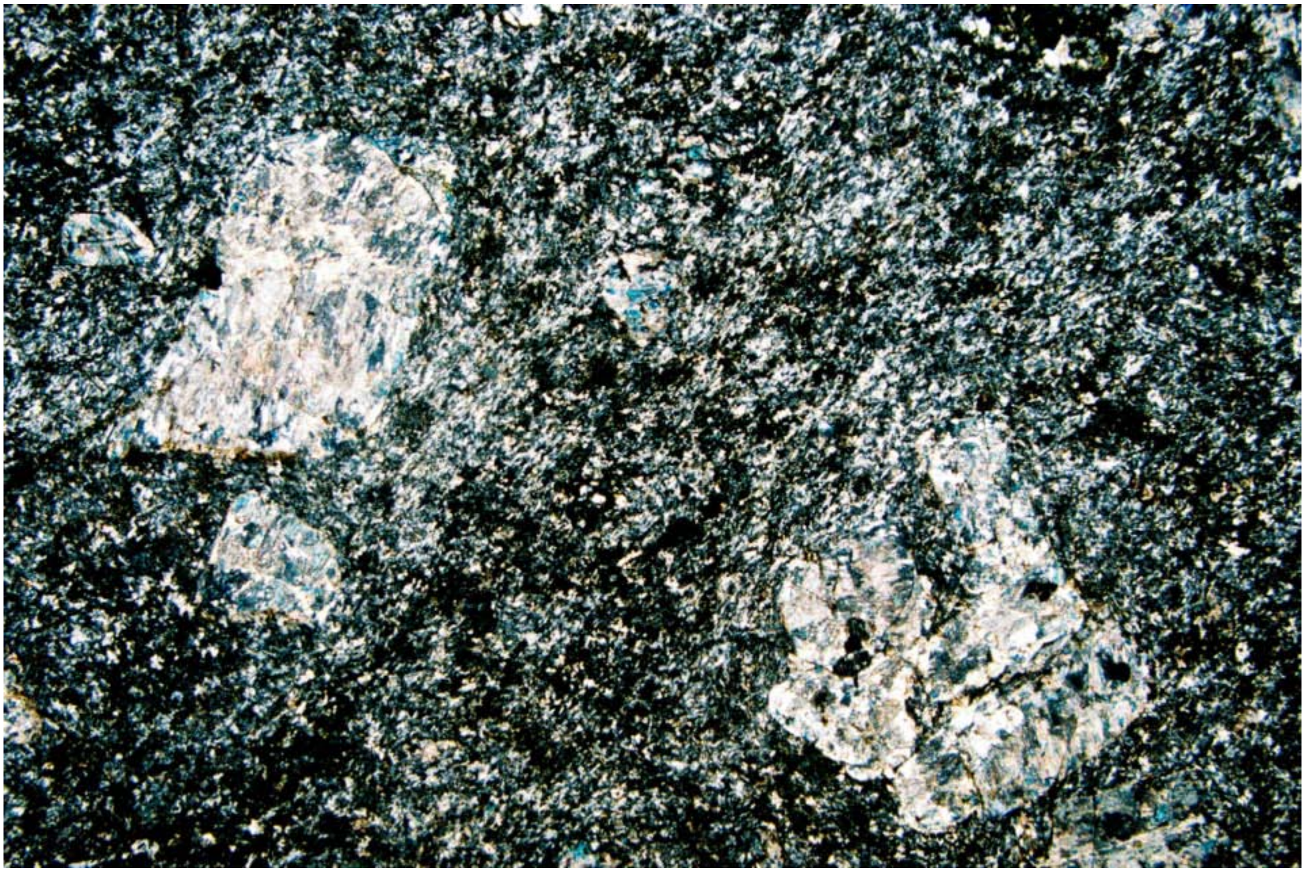
Vesicles (0%) and Xenoliths (0%) were not observed.

ALTERATION No other alteration features were observed.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOS Refer to next page.

MRE-SI7C 08042_09m.jpg/XPL/FOV = 4.00 x 5.83 mm/VZM HIGHLY ALTERED ANDESITE showing typical appearance.



SAMPLE # **MRE-SI8A**

ROCK NAME ALTERED FELSIC VOLCANIC ROCK -- probably formed by hydrothermal alteration (secondary quartz + chlorite + weakly ferroan dolomite).

MINERALS Microcrystalline [K-feldspar + plagioclase] (92%)+ quartz (2%) + chlorite (2%) + weakly ferroan dolomite (2%).

TEXTURES Aphanitic, holocrystalline, aphyric, very fine grained, non-directed fabric.

Phenocrysts (0%) are absent.

Groundmass (100%) is composed of finely intergrown anhedral [K-feldspar + plagioclase].

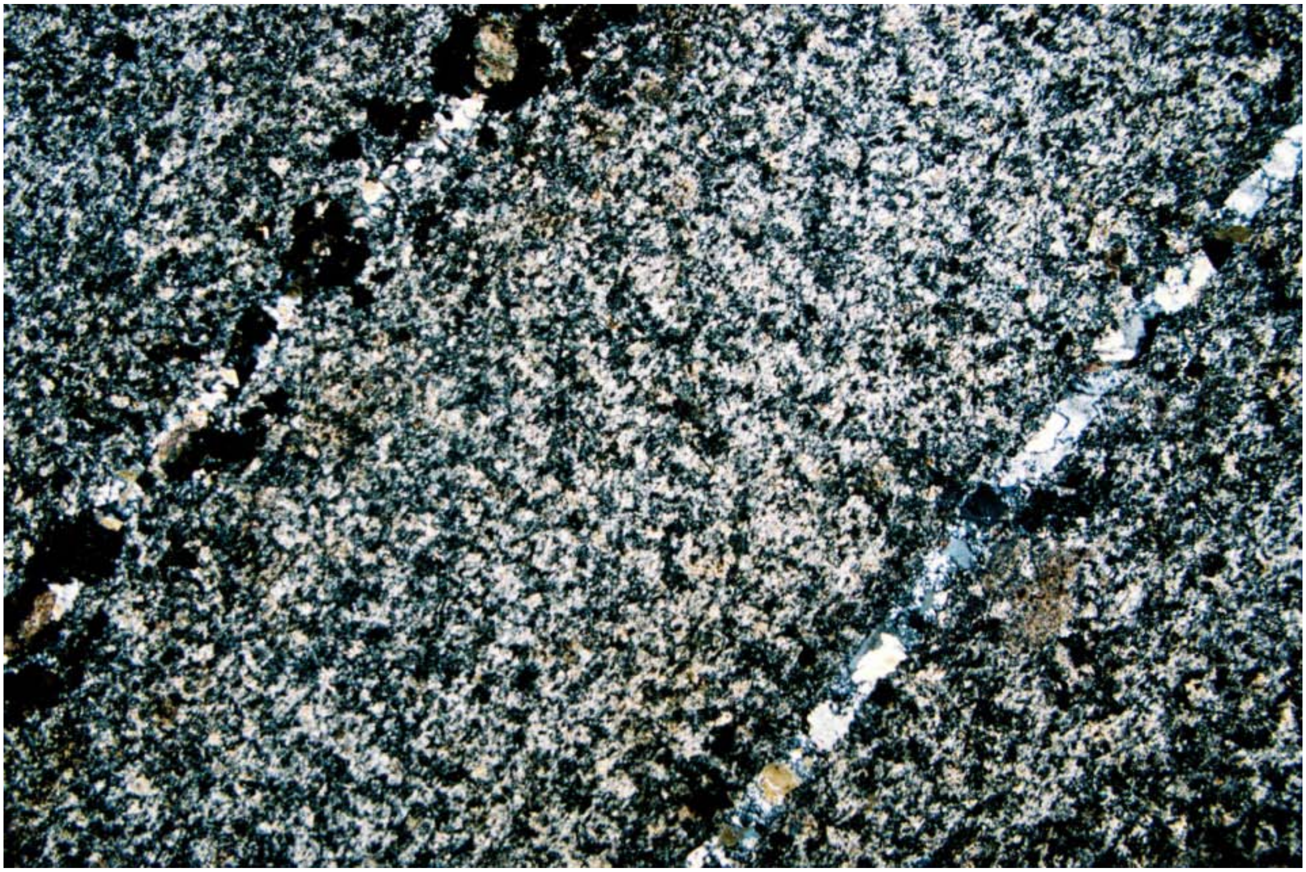
Vesicles (0%) and Xenoliths (0%) were not observed.

ALTERATION The following alteration features are also present but of indeterminate relative ages: (1) veins of quartz + weakly ferroan dolomite with discontinuous selvages of chlorite.

SECTIONING Format: 27 x 46 mm Finish: STD Stains: SCN (top 1/2) + [ARS + PF] (right 1/2) Cover: PLA

PHOTOS Refer to next page.

MRE-SI8A 204 08042_10m.jpg/XPL/FOV = 4.00 x 5.83 mm/VZM ALTERED FELSIC VOLCANIC ROCK showing typical fine grained appearance.



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January 16, 2009

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928.541.9895
bstrickler@fsrengineering.com

Subject:	X-ray Diffraction Analysis
Samples:	MRE-09-08, Sample #301, 59.0-59.3'
	RKS-19-07, Sample #301, 45-55'
K/T File No.:	Z09016

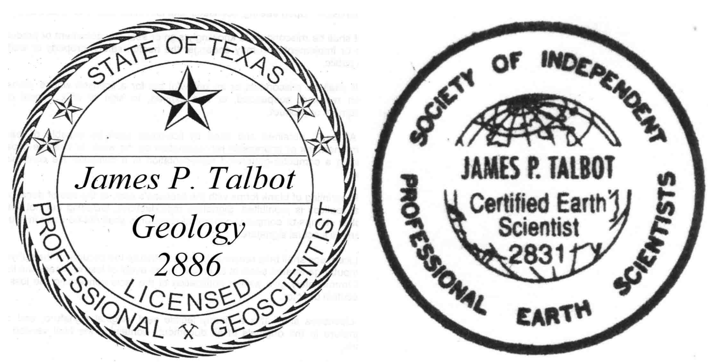
Dear Balin,

This report presents the results of bulk (whole rock) and clay fraction (<4 micron) X-ray diffraction (XRD) analysis performed on 2 samples. This analysis is performed to provide mineralogy of the samples.

Enclosed find the tabular XRD data (weight percentage), the X-ray diffraction traces and a detailed description of sample preparation and analytical procedures. For your convenience, I have sent a copy of this report via e-mail.

Unused portions of the samples will be returned upon request. If you have any questions concerning these results or if you need anything else please contact me at (940) 597-9076. Thank you for using K/T GeoServices to perform your X-ray diffraction analyses and I look forward to working with you again in the future.

Sincerely,



James P. Talbot, P.G.

X-ray Diffraction Data

Location	MRE-09-08	RKS-19-07
Sample#	301	301
Depth (ft)	59.0-59.3	45-55
Quartz	36.5	18.6
K Feldspar	3.1	0.6
Plagioclase	50.6	8.8
Calcite	0.4	9.5
Dolomite	1.4	0.0
Pyrite	0.3	0.0
Illite&Mica	1.4	0.0
Chlorite	5.5	0.6
R3 M-L I/S 10%S*	0.8	61.9
TOTAL	100.0	100.0

*R3 M-L I/S 10%S – Ordered Mixed-Layer Illite/Smectite with 10% Smectite Layers

See page 3 for mineral definitions.
See page 4 for a discussion of X-ray diffraction terminology and limitations.
Sample preparation and analytical procedures are on page 5.
X-ray diffraction traces are on pages 6 to 11.

Mineral Definitions
Phyllosilicate (Clay) Minerals

Illite & Mica
Illite & Mica (muscovite) are common non-expanding (non-swelling) minerals. Illite is the fine-grained clay mineral analogue to muscovite. Illite and Mica are hydrated silicates containing potassium, silica and alumina.

Chlorite
Chlorite is a common non-expanding (non-swelling) clay mineral. It is a hydrous aluminum silicate that often contains iron.

Mixed-Layer Illite/Smectite
A clay mineral group containing interlayered or interstratified Illite and Smectite. The mixed-layer clay type is identified by the minerals involved (Illite and Smectite in this case), the type of order or stacking along the Z axis (R3 ordered in this case), and the proportions of the minerals involved (90% Illite and 10% Smectite in this case).

Smectite (Montmorillonite)
A clay mineral group synonymous with the montmorillonite group. The smectite group is composed of expandable (swelling) clay minerals. The general formula for Smectite is $(Na,Ca)(Al,Mg)_6 (Si_4O_{10})_3(OH)_6 \bullet n\, H_2O$. Smectites are characterized by swelling in water and extreme colloidal behavior.

Rock Forming (nonclay) Minerals

Quartz
Quartz (SiO_2) is the most common rock-forming mineral.

K-Feldspar
K-Feldspar ($KAlSi_3O_8$) is a potassium bearing feldspar and can be Orthoclase, Microcline or Sanidine.

Plagioclase
Plagioclase is a mineral series ranging in composition from Albite ($NaAlSi_3O_8$) to Anorthite ($CaAl_2Si_2O_8$) and is one of the most common rock forming mineral groups.

Calcite
Calcite is a common hexagonal carbonate mineral with the formula $CaCO_3$.

Dolomite
Dolomite is a hexagonal carbonate mineral with the formula $CaMg(CO_3)_2$.

Pyrite
Pyrite (FeS_2) is an iron sulfide and is also known as fool's gold.

Reference for general mineral definitions: Dictionary of Geological Terms, American Geological Institute, 1976, Anchor Press/Doubleday, Garden City, New York.

K/T GeoServices, Inc.
Whole Rock and Clay Fraction XRD
Discussion of Terminology and Limitations

Weight percentage data from X-ray diffraction methods are considered semi-quantitative. There are many factors affecting the results.

XRD methods can quantify crystalline material only. Organic non-crystalline material in large concentrations can be detected but not quantified. Therefore, any organic and/or non-crystalline material is not included in the accompanying results.

Detection limits for XRD are on the order of one to five weight percent. The detection limits differ for each mineral species.

Mineral standards used to determine calibration factors are often different from the actual minerals analyzed. Minerals such as feldspars that undergo solid solution are especially problematic. Clay minerals are problematic for this same reason. Clay minerals also have a wide range of crystallinities (poorly crystallized to well crystallized) which may compound this problem.

With this method the data always sums to 100%. This means that the percentages reported for each mineral are dependent upon the percentages reported for the other minerals. If one mineral is underestimated the others will be overestimated. Also, if one or more minerals are present but not detected then the percentages of the minerals that are detected will be overestimated.

Any or all of the above factors may affect the estimated weight percentages.

Data are formatted as weight percent, but are actually calculated as weight fractions. Therefore, slight rounding errors may be observed in the formatted data.

For this analytical method, the clay fraction is defined as the <4 micron ESD (Equivalent Spherical Diameter) fraction of the sample. Clay fraction does not mean clay minerals (phyllosilicates) only, it is a size term and as such this size fraction can and almost always does include non-clay minerals (quartz, plagioclase, etc.). This size fraction is used because it typically contains abundant clay minerals.

K/T GeoServices, Inc.
Whole Rock and Clay Fraction XRD
Sample Preparation and Analytical Procedures

Sample Preparation

Samples submitted for whole rock and clay mineral XRD analyses are cleaned of obvious contaminants and disaggregated in a mortar and pestle. A split of each sample is then transferred to distilled water and pulverized using a McCrone micronizing mill. The resultant powder is dried, disaggregated, and packed into a metal sample holder to produce random whole-rock mounts. A separate split of each sample is dispersed in distilled water using a sonic probe. The suspensions are then size fractionated with a centrifuge to isolate clay-size (<4 micron equivalent spherical diameter) materials for a separate clay mount. The suspensions are then vacuum deposited on nylon membrane filters to produce oriented clay mineral mounts. The clay mineral mounts are attached to glass slides and exposed to ethylene glycol vapor for approximately 12 hours.

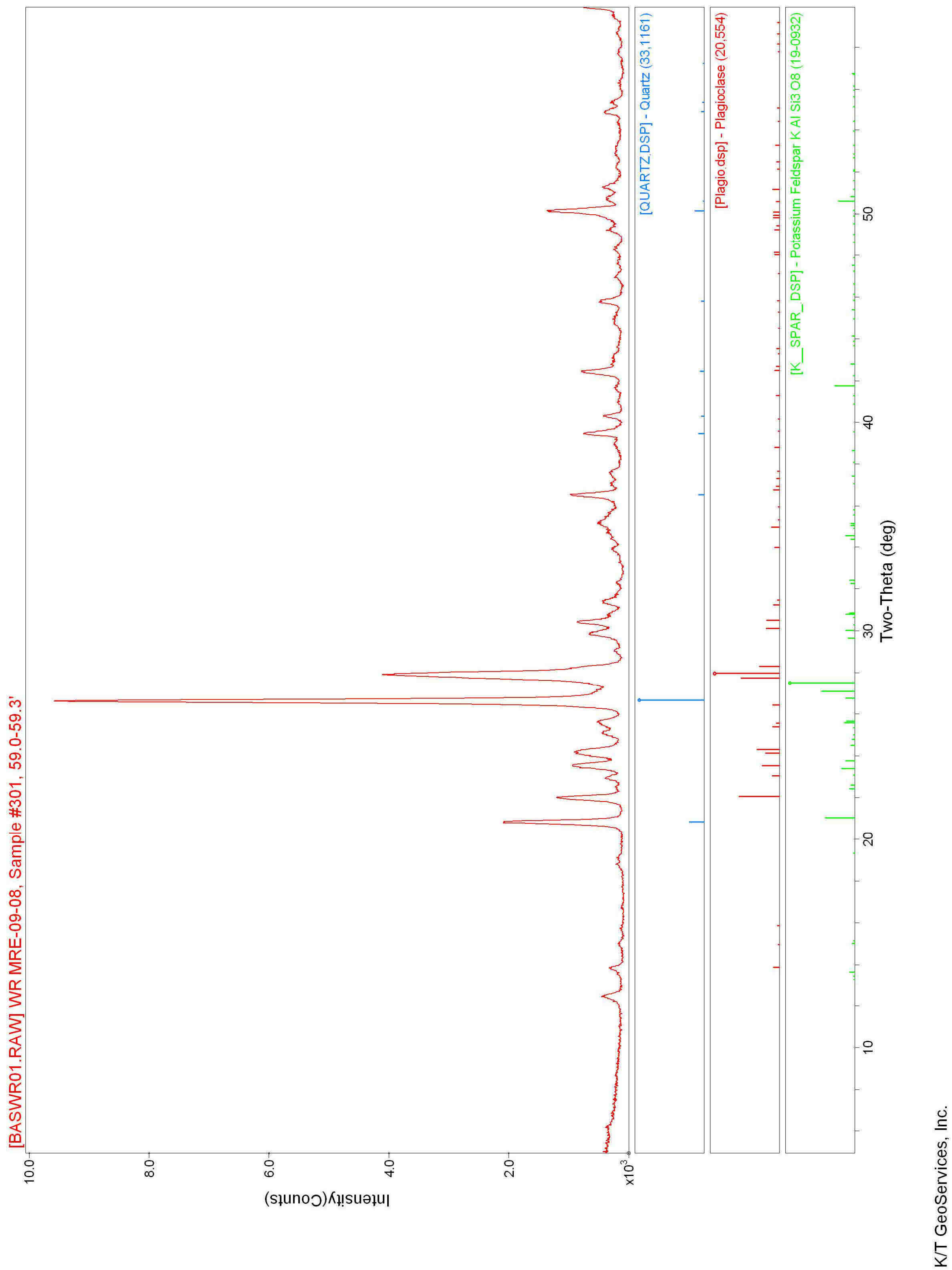
Analytical Procedures

X-ray Diffraction (XRD) analyses of the samples are performed using a Siemens D500 automated powder diffractometer equipped with a copper X-ray source (40kV, 30mA) and a scintillation X-ray detector. The whole rock samples are analyzed over an angular range of five to sixty degrees two theta at a scan rate of one degree per minute. The glycol solvated oriented clay mounts are analyzed over an angular range of two to thirty six degrees two theta at a scan rate of one degree per minute.

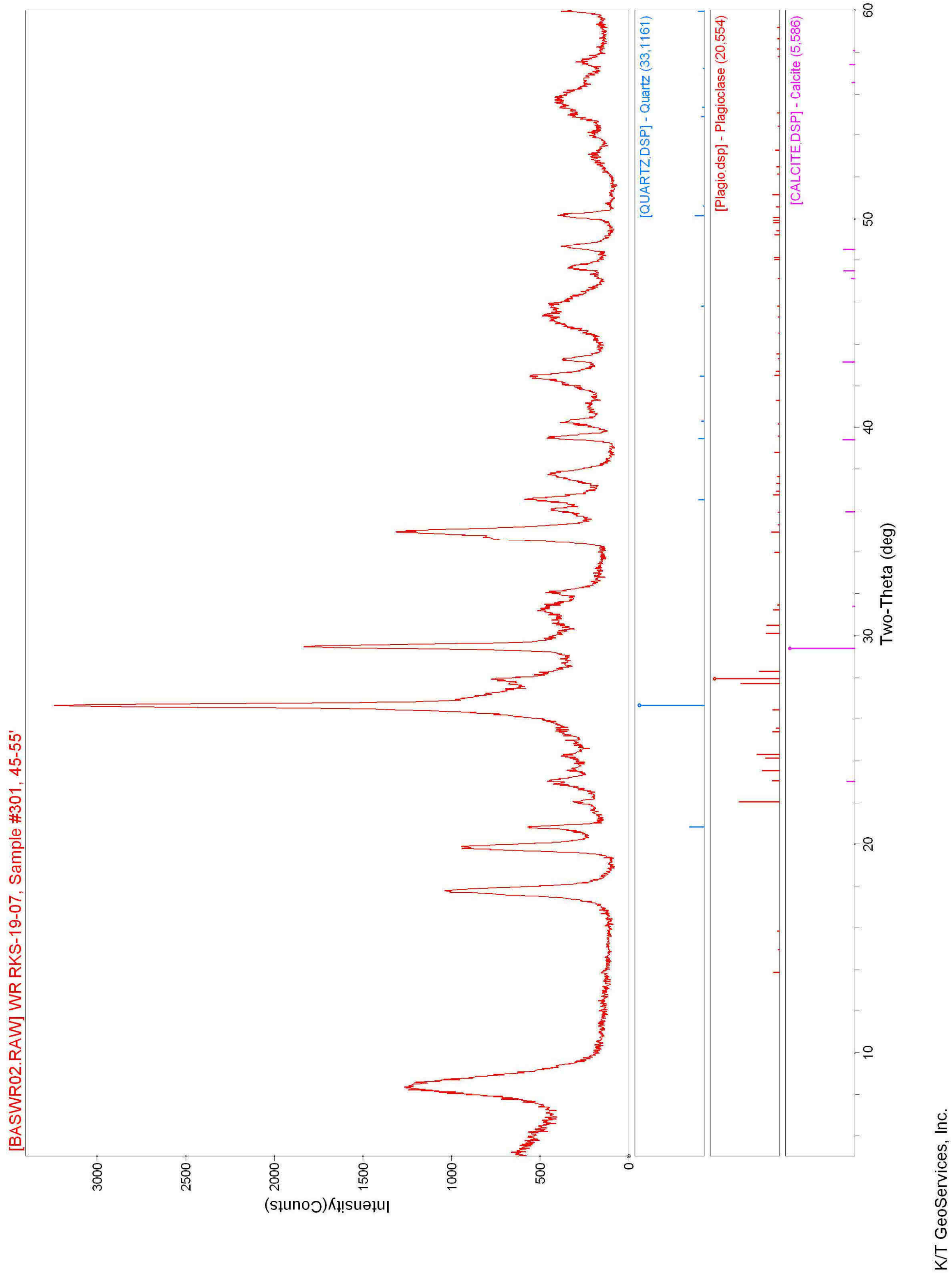
Semiquantitative determinations of whole-rock mineral amounts are done utilizing integrated peak areas (derived from peak-decomposition / profile-fitting methods) and empirical reference intensity ratio (RIR) factors determined specifically for the diffractometer used in data collection. The total phyllosilicate (clay and mica) abundance of the samples are determined on the whole-rock XRD patterns using combined {00l} and {hkl} clay mineral reflections and suitable empirical RIR factors.

XRD patterns from glycol-solvated clay-fraction samples are analyzed using techniques similar to those described above. The relative amounts of phyllosilicate minerals are determined from the patterns using profile-fitted integrated peak intensities and combined empirical and calculated RIR factors. Determinations of mixed-layer clay ordering and expandability are done by comparing experimental diffraction data from the glycol-solvated clay mounts with simulated one dimensional diffraction profiles generated using the program NEWMOD written by R. C. Reynolds.

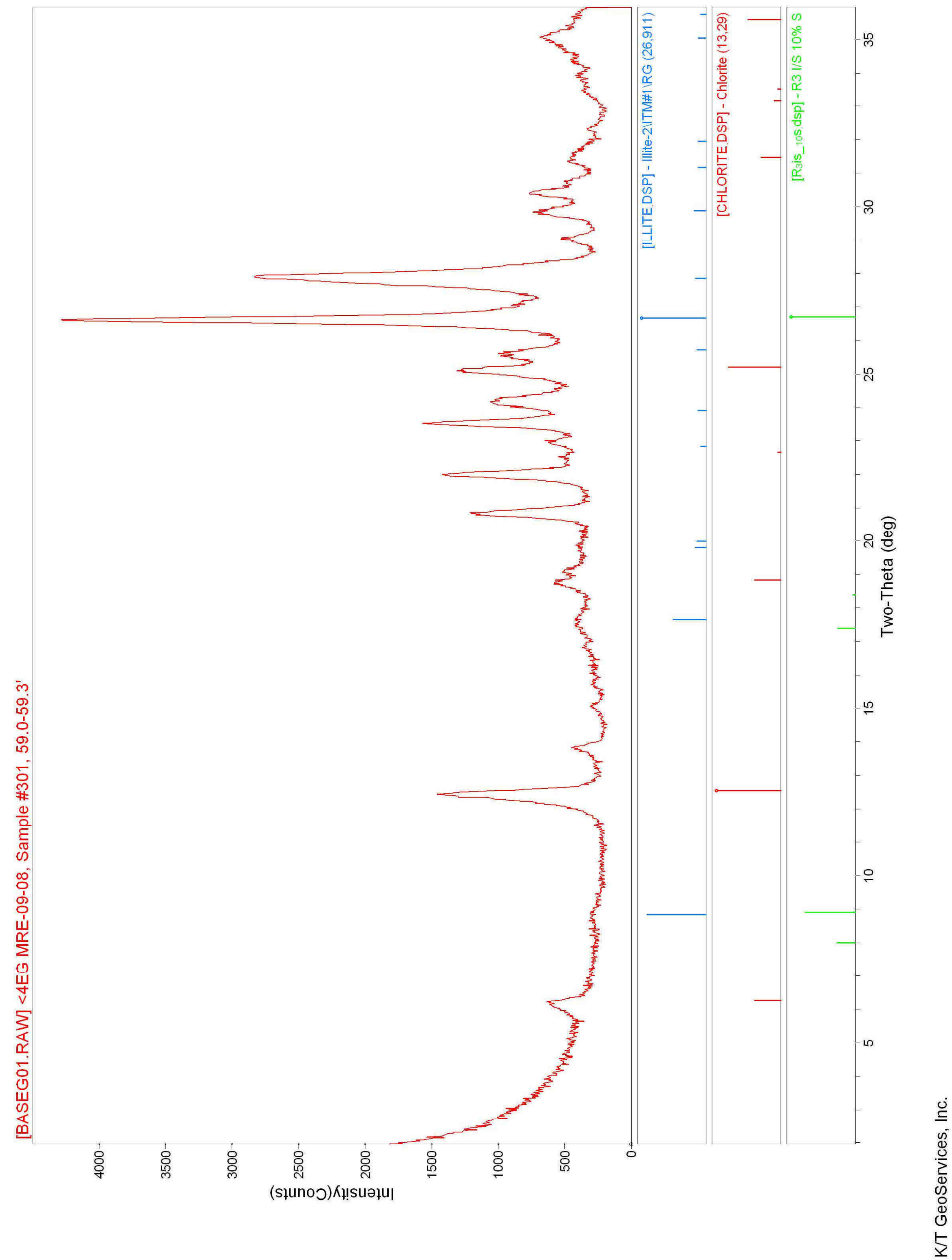
Bulk (Whole Rock) X-ray Diffraction Trace
MRE-09-08, Sample #301, 59.0-59.3'



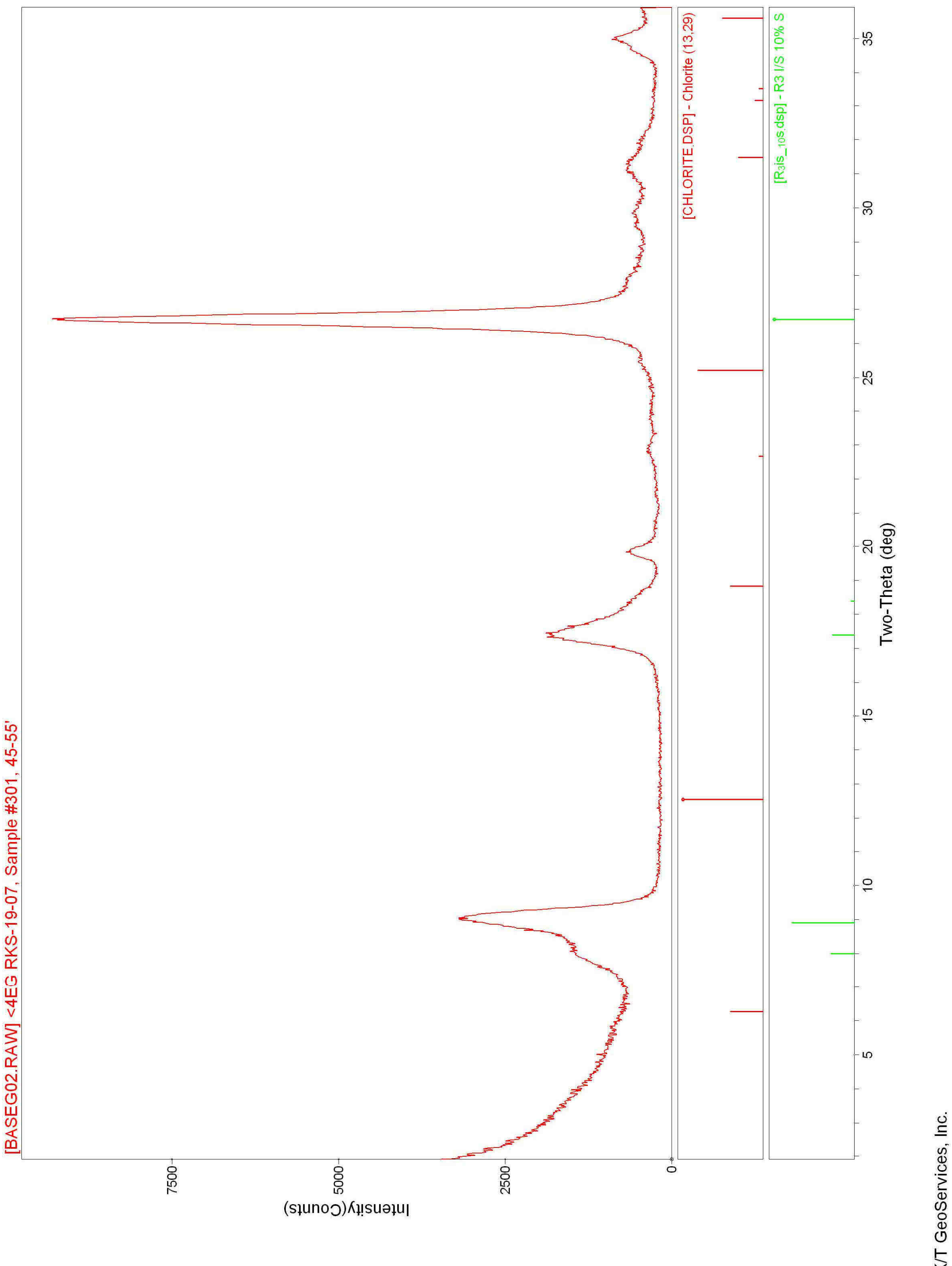
Bulk (Whole Rock) X-ray Diffraction Trace
RKS-19-07, Sample #301, 45-55'



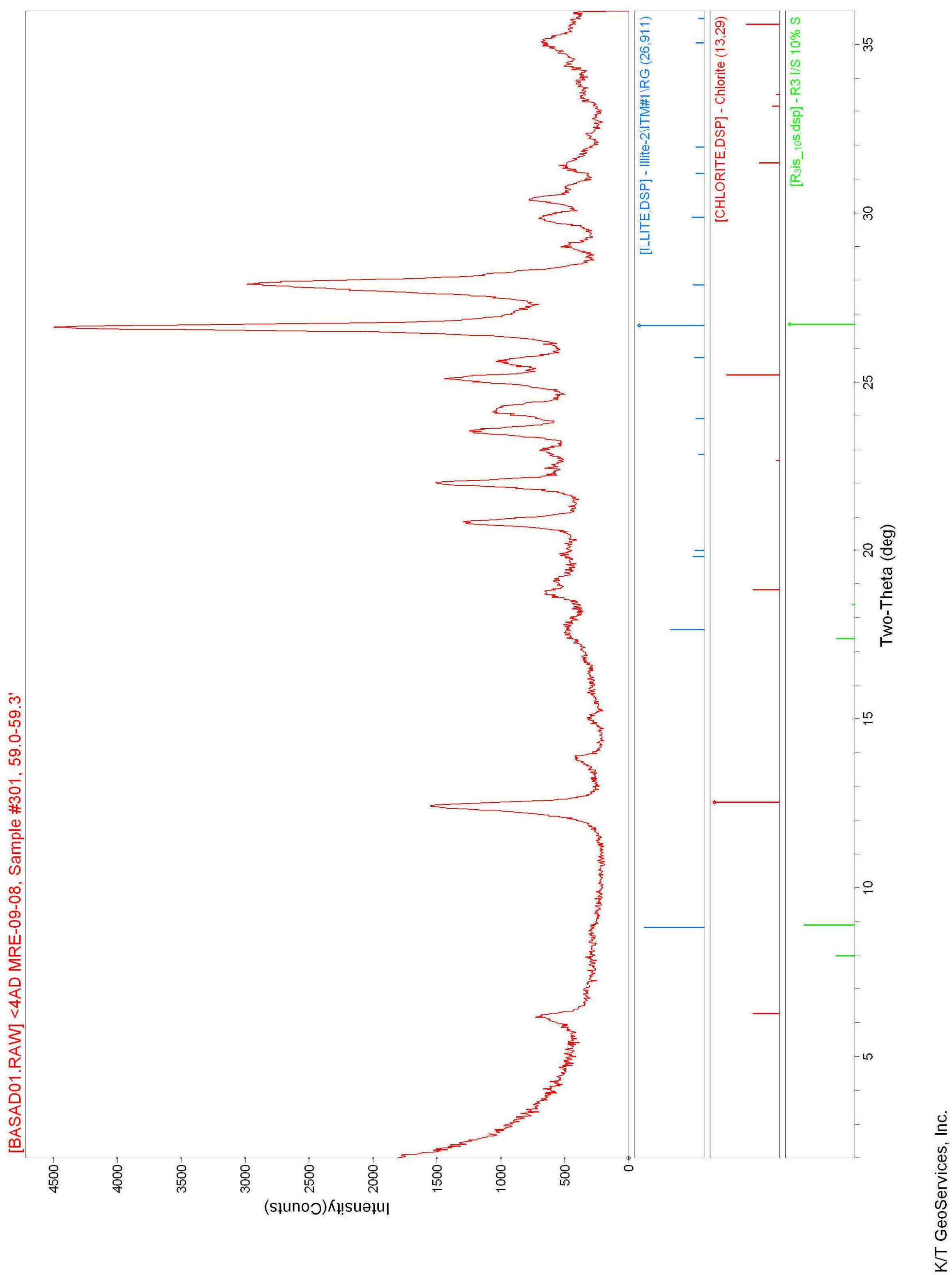
Ethylene Glycol Solvated Clay Fraction (<4 micron) X-ray Diffraction Trace
MRE-09-08, Sample #301, 59.0-59.3'



Ethylene Glycol Solvated Clay Fraction (<4 micron) X-ray Diffraction Trace
RKS-19-07, Sample #301, 45-55'



Air-Dried Clay Fraction (<4 micron) X-ray Diffraction Trace
MRE-09-08, Sample #301, 59.0-59.3'



Air-Dried Clay Fraction (<4 micron) X-ray Diffraction Trace
RKS-19-07, Sample #301, 45-55'