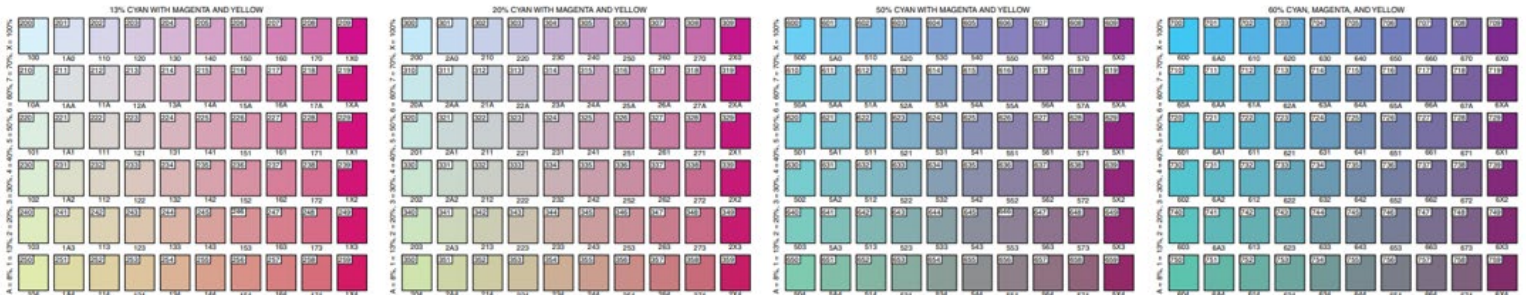
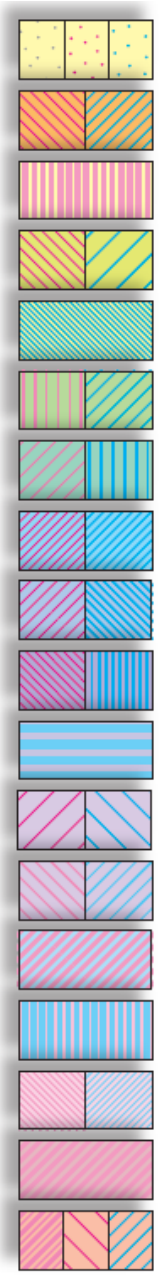
COLOR OPTIMIZATION METRICS FOR GEOLOGIC MAPS

Beyond the Basics of Geologic Map Database QA/QC



Ally Steinleitner
UCGIS Week, 11/20/2025

Alaska Division of Geological & Geophysical Surveys
3354 College Rd, Fairbanks AK 99709



UCLA College | Social Sciences Geography

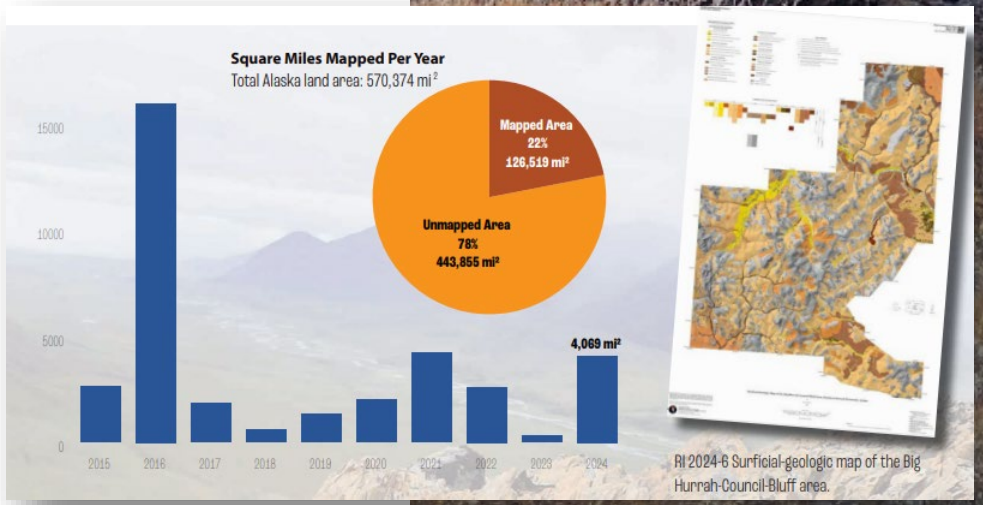
STATE OF ALASKA
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

AKDGGS

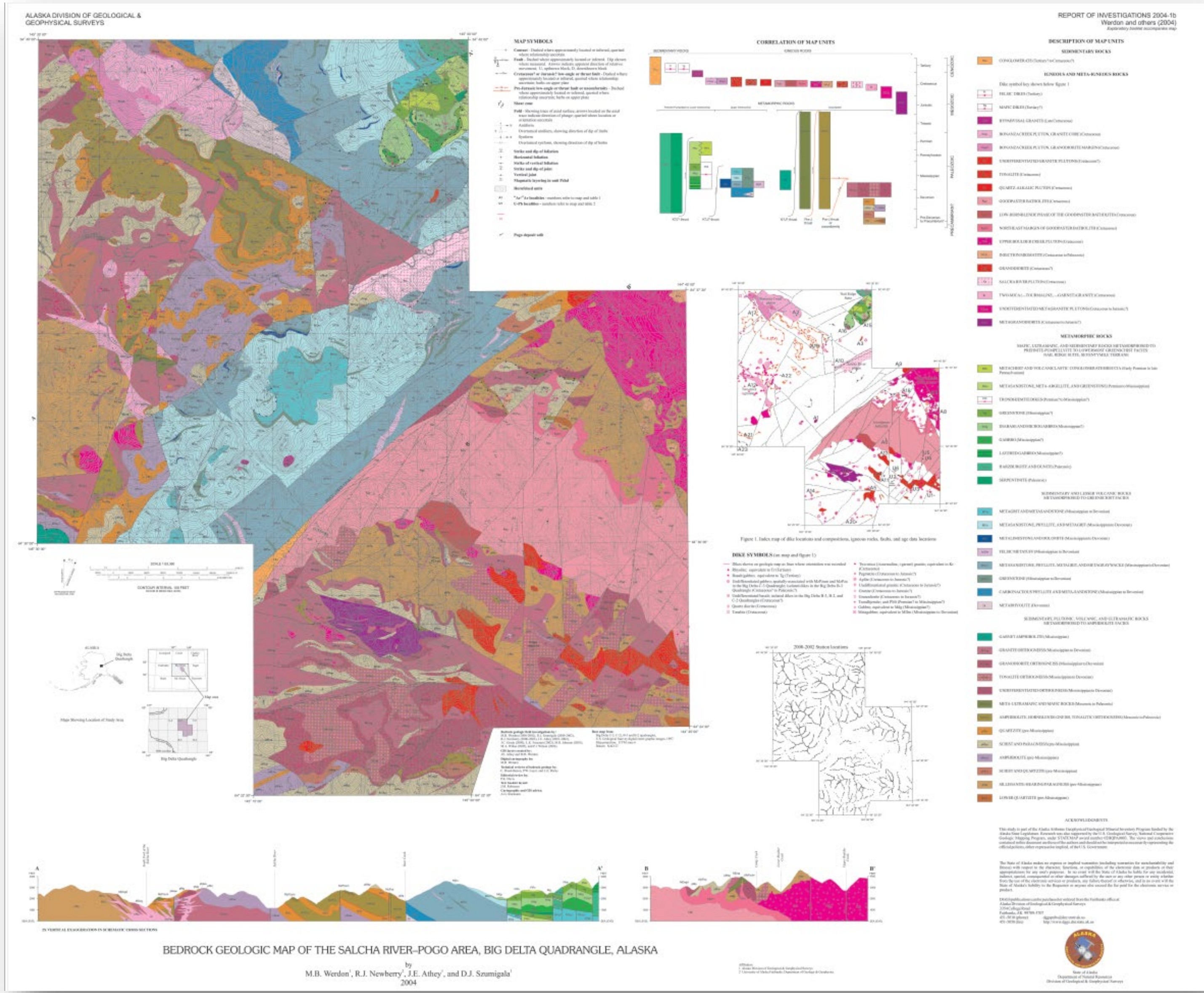
Alaska Geologic Mapping

- Resource exploration
- Land use management
- Geologic hazards assessment

We served over 30 TB of digital geologic data and information from the DGGS website (dggs.alaska.gov) and geoportals



State of Alaska
Department of Natural Resources
Alaska Division of Geological & Geophysical Surveys


ALASKA DIVISION OF GEOLOGICAL &
GEOPHYSICAL SURVEYS
REPORT OF INVESTIGATIONS 2004-1b
Werdon and others (2004)
MAP SYMBOLS
CORRELATION OF MAP UNITS
DESCRIPTION OF MAP UNITS
SEDIMENTARY ROCKS
IGNEOUS AND META-IGNEOUS ROCKS
METAMORPHIC ROCKS
DIKE SYMBOLS
ACKNOWLEDGMENTS
BEDROCK GEOLOGIC MAP OF THE SALCHA RIVER–POGO AREA, BIG DELTA QUADRANGLE, ALASKA
by
M.B. Werdon[1], R.J. Newberry[2], J.E. Athey[1], and D.J. Szumigala[1]
2004

Alaska DGGS Geologic Mapping System Components

Organizational Procedures

Tools

AK GeMS v2 Data Dictionary

Alaska DGGS
Field Event Geodatabases

Mapping Process

Alaska DGGS
Single Map AK GeMS Production DBs

Convert & Load

Alaska DGGS
Multi Map AK GeMS Geodatabase

Geologic Feature Services

Product Web Page

Digital Data Series (DDS) File Geodatabase Export Snapshots

Cartographic Product

Saved to \\decima.dnr.state.ak.us\office_share

Print, pdf, & Rasterize

Geologic Map Image Services

Product Web Page

Export

Alaska DGGS
Single Map AK GeMS Geodatabase

Convert

USGS
Single Map GeMS Geodatabase

To USGS

GeMS Validation

Style

AK GeMS v2 Symbology

Quality Control

Data Reviewer Rules & Python Tools

Four Categories of Production

- *New Mapping*
- *Conversions*
- *Digitizations*
- *Compilations*

AK GEMS DATA DICTIONARY: A DESCRIPTION OF THE AK GEMS DATABASE SCHEMA, MP 170 V.2
https://dggs.alaska.gov/pubs/id/31172

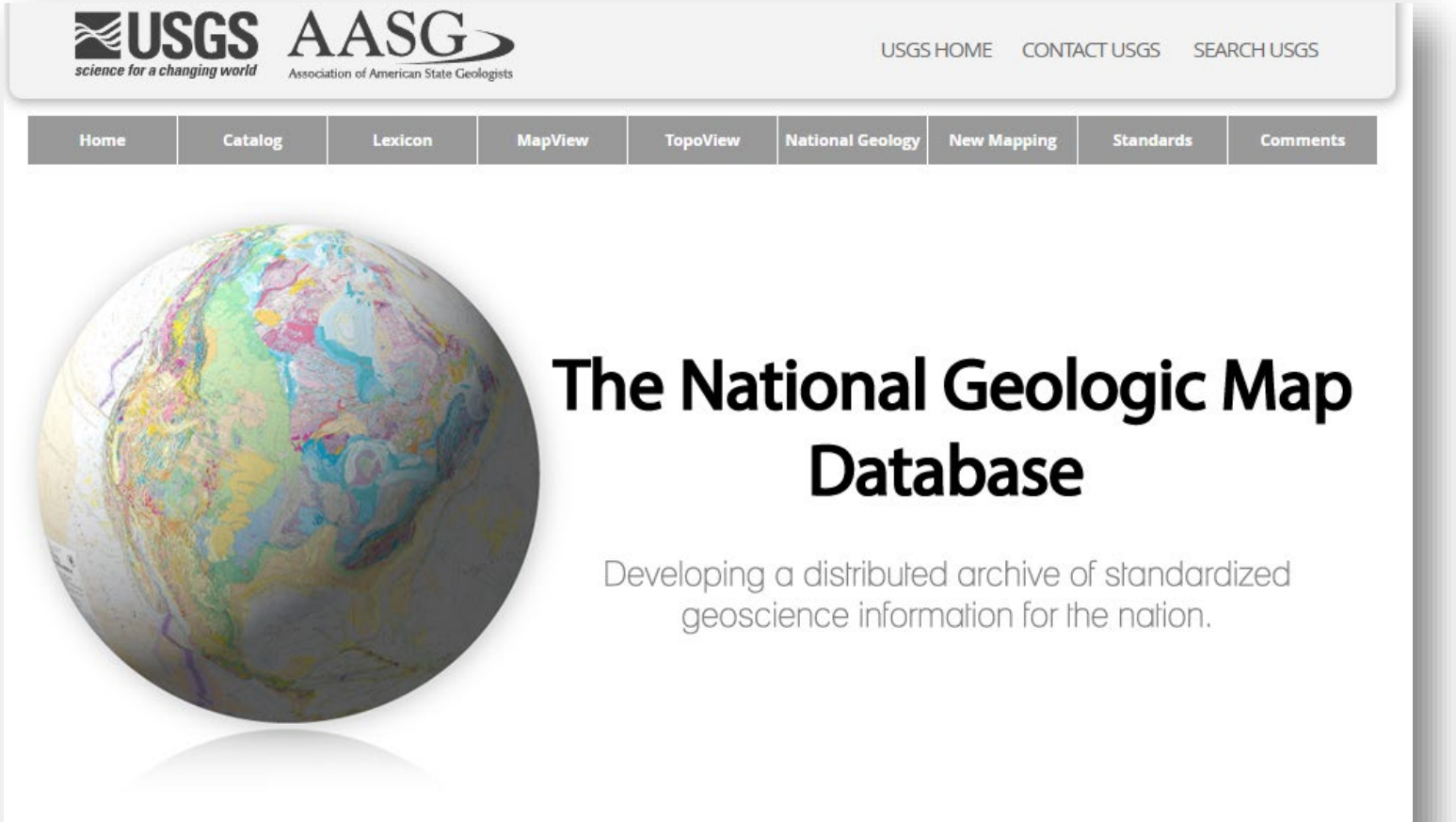
- Report
- Data Dictionary
- Entity-Relationship Diagram
- XML Workspace Document

AK GEMS SYMBOLOGY: A DESCRIPTION OF THE AK GEMS STYLE FILE, MP 169 V.2
https://dggs.alaska.gov/pubs/id/31101

- Report
- AK_GeMS_symbology_documentation_ver_2.xls (Excel)
- AK_GeMS_symbology_ver_2.style (Style File)

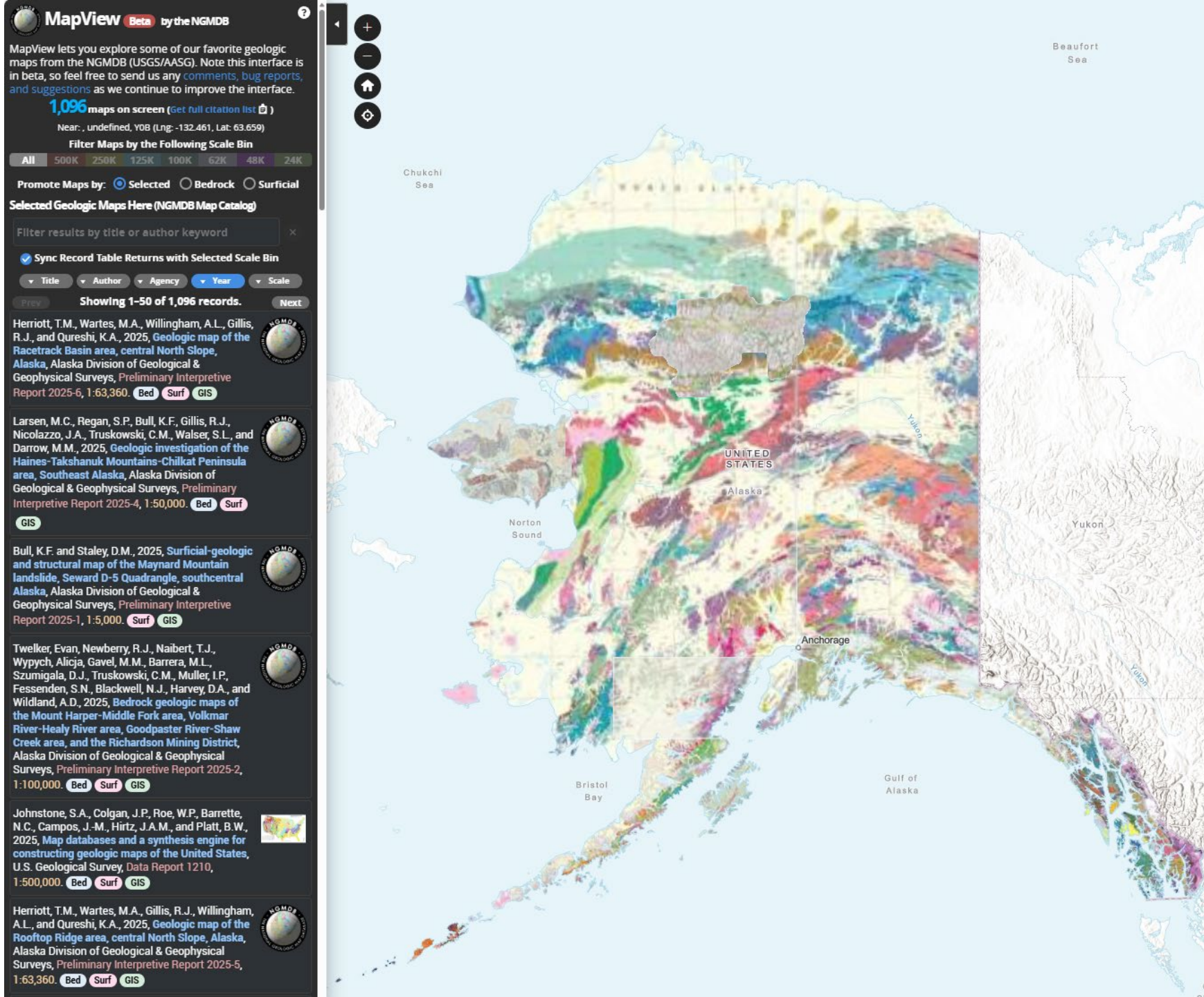
Geologic Map Standard (GeMS)

- Standardized database schema for digital publication of geologic maps
- For geologic maps published by USGS and state surveys



National Geologic Map Database (NGMDB)

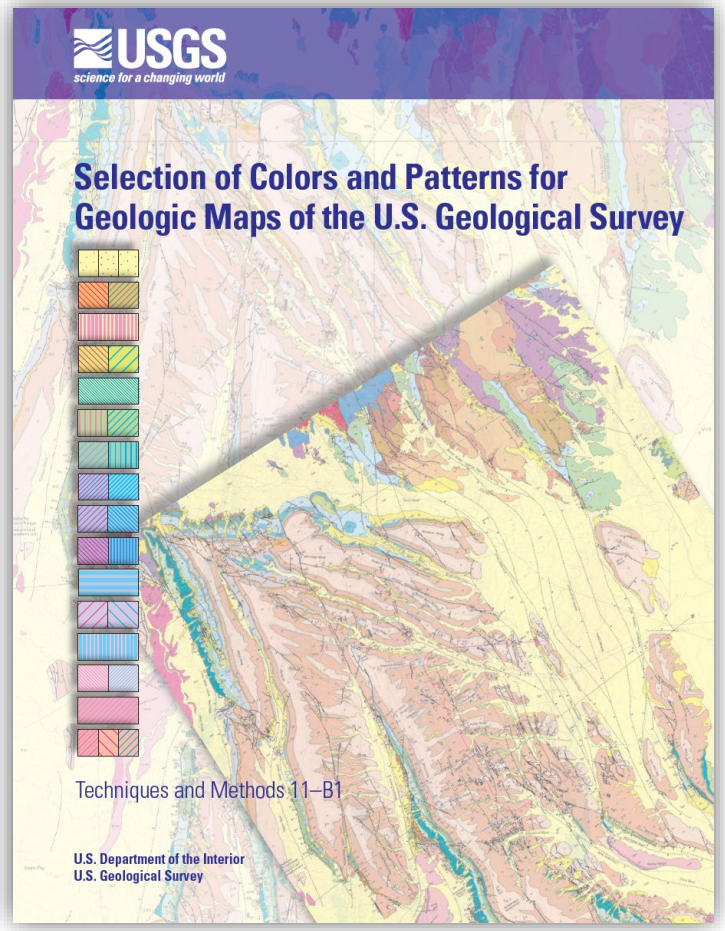
- Multimap geologic map database

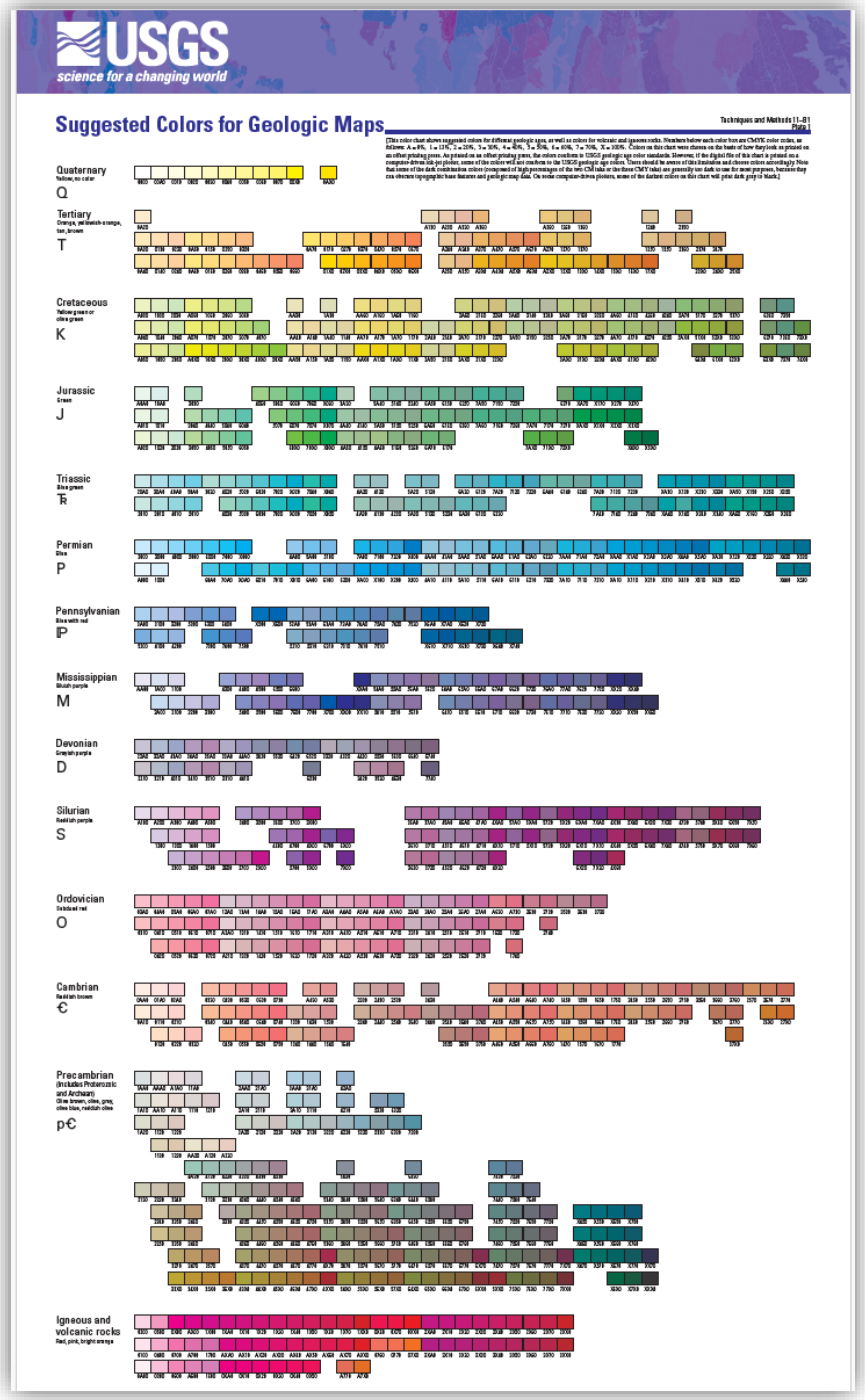


FGDC Geologic Color Standards

USGS Techniques and Methods 11-B1

- Purpose and use of the map
- Legibility of the map
- Showing contrast and clarity of map units and symbols
- Showing ages or age relationships of map units
- Showing structural relationships of map units
- Matching or approximating colors and patterns used on nearby or adjacent maps to maintain consistency and continuity of colors and patterns among maps in a region





Suggested Colors for Geologic Maps

Table 1. Suggested colors for geologic maps. CMYK values: A = 8%, 1 = 13%, 2 = 20%, 3 = 30%, 4 = 40%, 5 = 50%, 6 = 60%, 7 = 70%, X = 100%.

Geologic age	Basic color	Color combination	Selected color samples
Quaternary Q	Yellow or no color (white)	Tints of yellow (30% and 50% are best to use, except in narrow bands or very small areas) or no color (white).	0000 0030 0050 00X0
Tertiary T	Orange, yellowish orange, tan, brown	Combinations of yellow and magenta, with proportionally more yellow than magenta.	A130 0270 A570 16X0
Cretaceous K	Yellow green or olive green	Combinations of yellow and cyan, with proportionally more yellow than cyan; the addition of a small proportion of magenta produces olive greens.	A030 3070 4260 63X0
Jurassic J	Green	Combinations of yellow and cyan in equal or nearly equal proportions. Note: in theory, this is the correct color for Jurassic; however, in practice it is well to lean toward the conventional "blue greens" when possible.	3030 6060 6160 X0X0
Triassic Ŧ	Blue green	Combinations of yellow and cyan, with proportionally more cyan than yellow.	30A0 5030 6A30 6240
Permian P	Blue	Tints of cyan; a small proportion of magenta is often needed to increase contrast.	2000 5000 6200 62A0
Pennsylvanian ℙ	Blue with red	Combinations of cyan and magenta, with a much higher proportion of cyan than magenta.	3A00 3200 53A0 6400
Mississippian M	Bluish purple	Combinations of cyan and magenta, with the proportion of cyan only slightly higher than magenta.	1100 4300 5400 6500
Devonian D	Grayish purple	Combinations of equal or nearly equal proportions of magenta and cyan plus a low proportion of yellow.	32A0 3310 54A0 6410
Silurian S	Reddish purple	Combinations of magenta and cyan, with proportionally more magenta than cyan.	1200 1500 3400 3620
Ordovician O	Subdued red	Light tints of magenta or combinations of a high proportion of magenta with low proportions of yellow and cyan.	03A0 1310 2410 2630
Cambrian €	Reddish brown	Combinations of magenta and yellow in equal or nearly equal proportions plus a low proportion of cyan.	0120 1430 1660 3640
Precambrian* p€	Olive brown, olive, gray, olive blue, reddish olive	Combinations of equal or nearly equal proportions of yellow, magenta, and cyan.	11A0 4430 1240 3560 2140 5370 3220 6430

*Includes Proterozoic and Archean.

Challenges

Large maps with many map units

- Particularly large number of map units of any one geologic age

Guidance :

- select colors that maintain the relative order of colors on the geologic age column but move up and (or) down on the column.
- use the color immediately above the geologic age color for the youngest units, the correct color for the middle units, and the color immediately below the geologic age for the older units.

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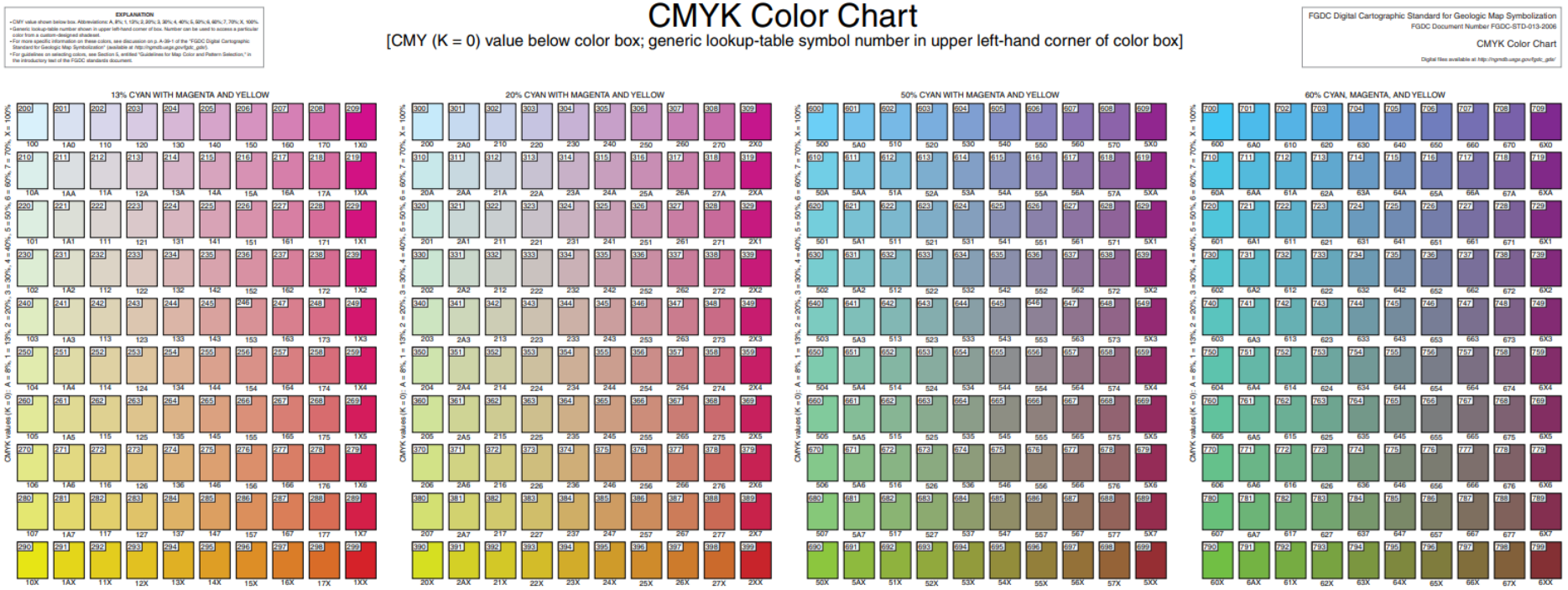
*Includes Proterozoic and Archean.

FGDC Recommendations

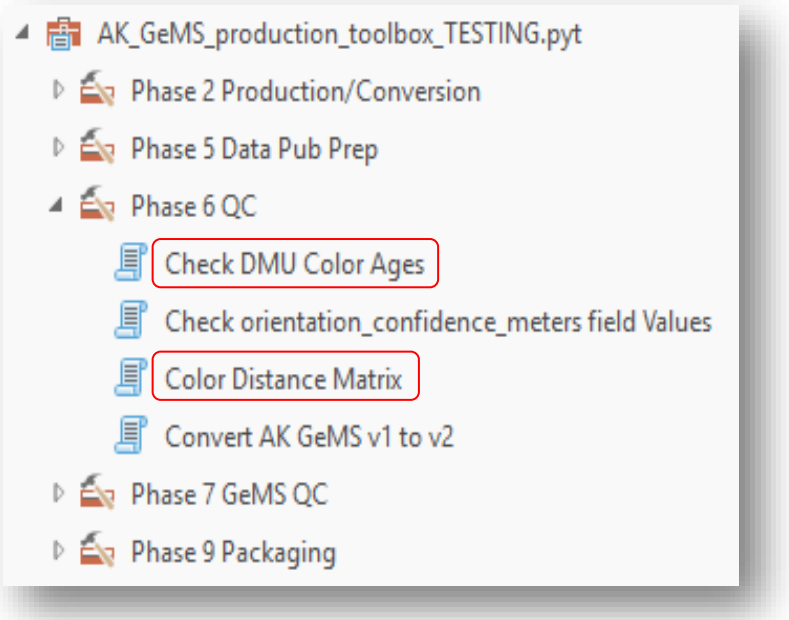
- CYMK colors that differ by at least 30% for computer driven plotters
- Colors maintain the relative order of colors on the geologic age column



Developing Metrics

1. Human Readability
   - Color Distance Matrix Tool

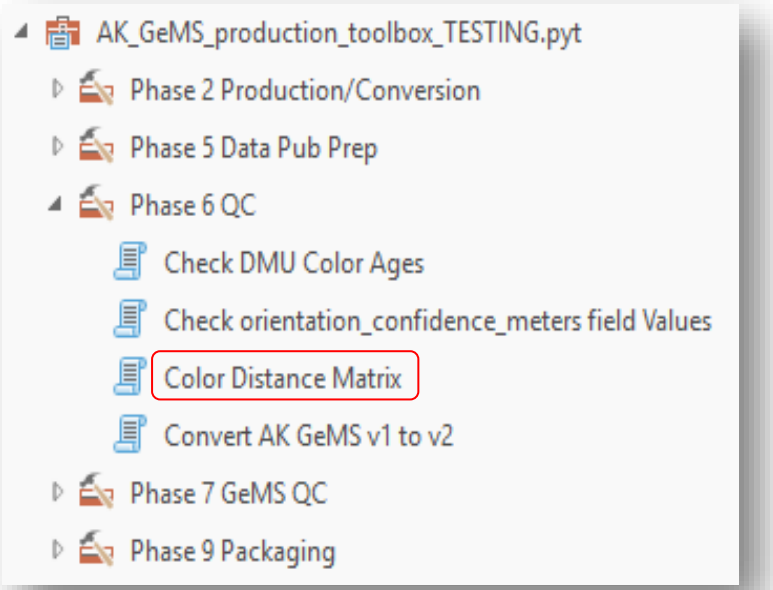
2. Adherence to Color Standards
   - Check DMU Color Ages Tool



Exist in AK_GeMS_production_toolbox.pyt

Color Distance Matrix Tool

- Distance matrix of Euclidean distance between colors in DMU
- Average Euclidean distance between colors for a map

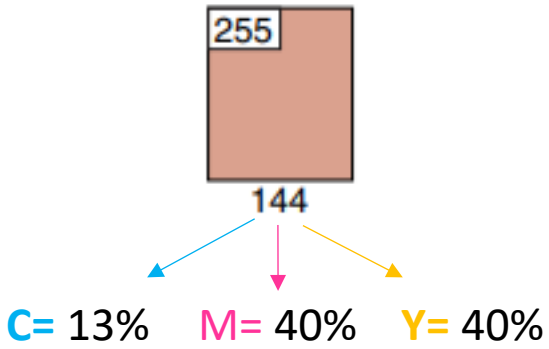


Map Unit	0010 Qal	0040 Qg	2030 Ksbls	3A40 Ksblb	2040 Ksblr	3150 Ktu	1050 Ks	4160 Kn	4240 Kt	Nearest Map Unit Color
Qal										
Qg	27									Qal
Ksbls	26.2	22.4								Qg
Ksblb	41.1	31	16.2							Ksbls
Ksblr	33.6	20	10	12.8						Ksbls
Ktu	49.4	34.2	25.9	11.2	19.2					Ksblb
Ks	39.2	16.4	21.2	21.3	12.2	21.4				Ksblr
Kn	63.1	46.6	38.3	22.9	31.1	14.1	31.6			Ktu
Kt	52.2	44.7	30	15.6	28.3	15.8	35.1	21.2		Ksblb
Average Dist	41.475	30.75714	23.6	16.76	22.7	17.1	33.35	21.2		25.86777

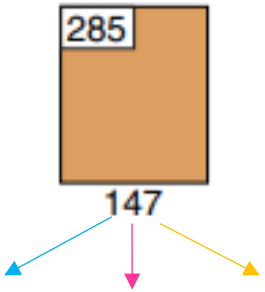
FGDC CMYK Color Chart

EXPLANATION

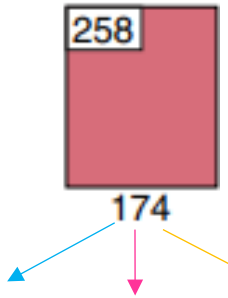
CMY value shown below box. Abbreviations: A, 8%; 1, 13%; 2, 20%; 3, 30%; 4, 40%; 5, 50%; 6, 60%; 7, 70%; X, 100%.



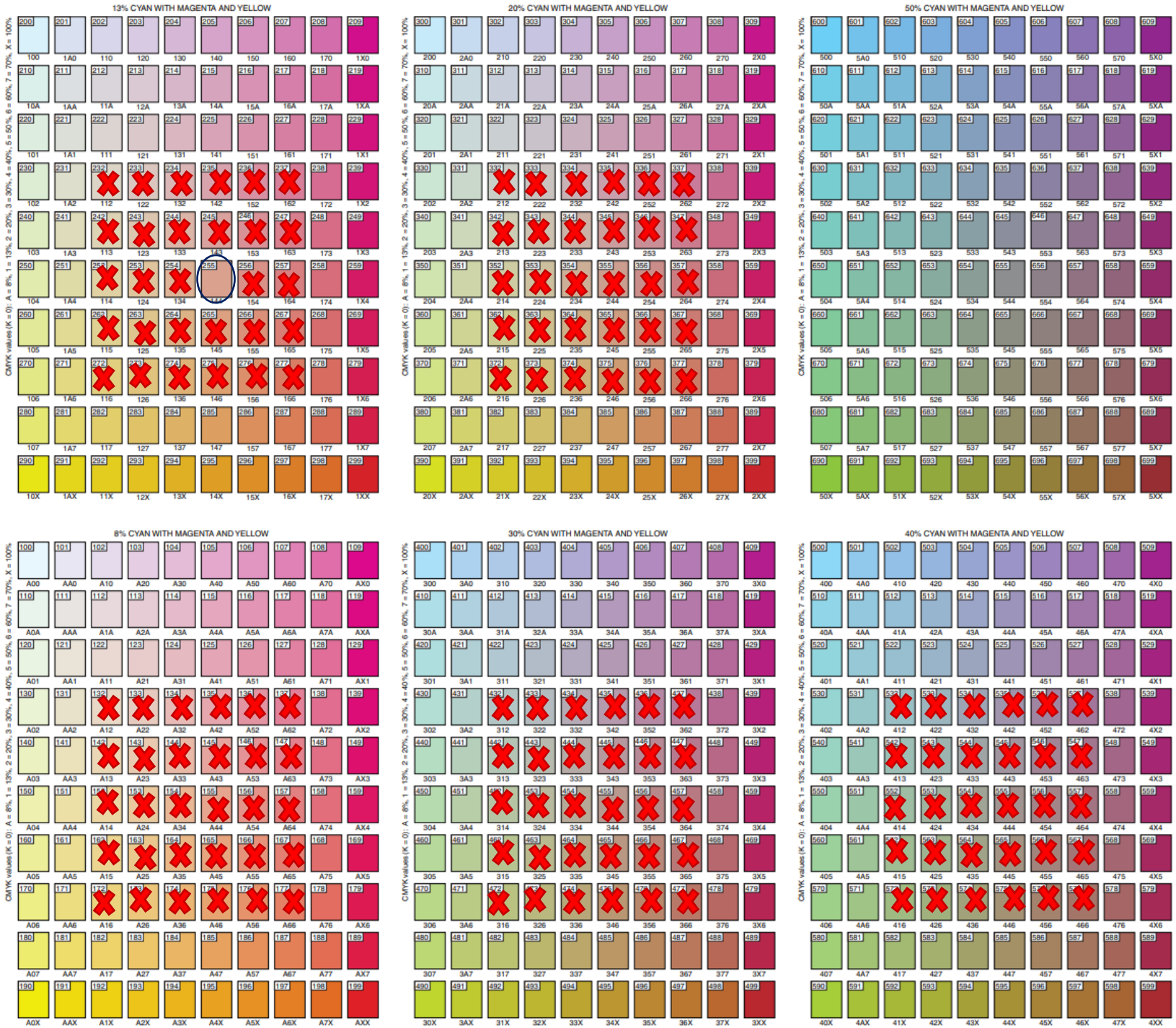
C= 13% M= 40% Y= 40%



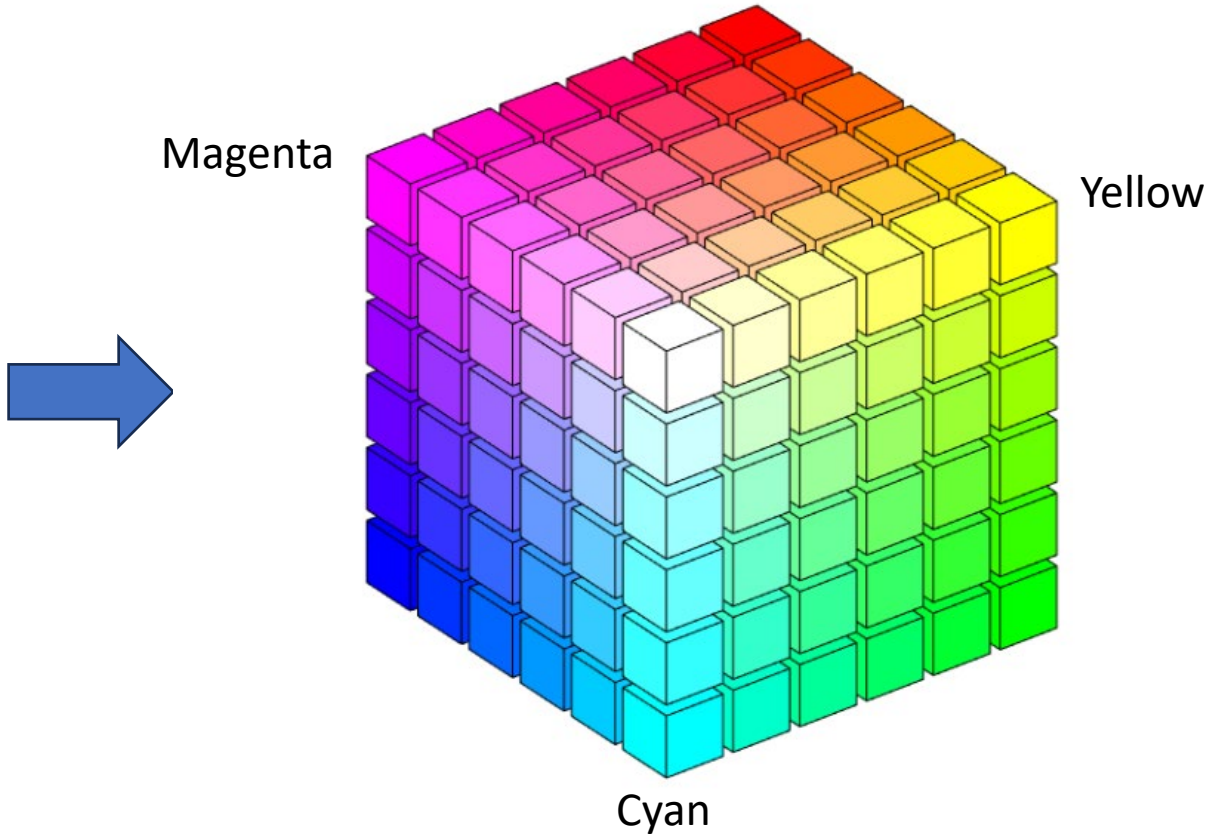
C= 13% M= 40% Y= 70%



C= 13% M= 70% Y= 40%

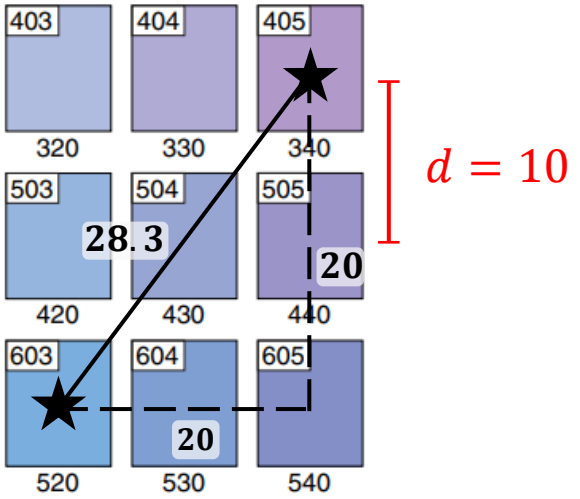

13% CYAN WITH MAGENTA AND YELLOW
20% CYAN WITH MAGENTA AND YELLOW
50% CYAN WITH MAGENTA AND YELLOW
8% CYAN WITH MAGENTA AND YELLOW
30% CYAN WITH MAGENTA AND YELLOW
40% CYAN WITH MAGENTA AND YELLOW
CMYK values (K = 0): A = 8%, 1 = 13%, 2 = 20%, 3 = 30%, 4 = 40%, 5 = 50%, 6 = 60%, 7 = 70%, X = 100%

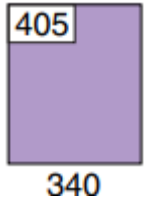

CMYK Color Chart
[CMY (K = 0) value below color box; generic lookup-table symbol number in upper left-hand corner of color box]
13% CYAN WITH MAGENTA AND YELLOW
20% CYAN WITH MAGENTA AND YELLOW
50% CYAN WITH MAGENTA AND YELLOW
60% CYAN, MAGENTA, AND YELLOW
8% CYAN WITH MAGENTA AND YELLOW
30% CYAN WITH MAGENTA AND YELLOW
40% CYAN WITH MAGENTA AND YELLOW
70% CYAN, MAGENTA, AND YELLOW
MAGENTA AND YELLOW
CYAN AND YELLOW
CYAN AND MAGENTA
100% CYAN WITH MAGENTA AND YELLOW


Magenta
Yellow
Cyan

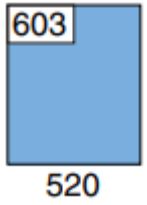
Color Distance Matrix Tool

Calculate the Euclidean distance between map units on 3D color cube





C= 30% M= 40% Y= 0%

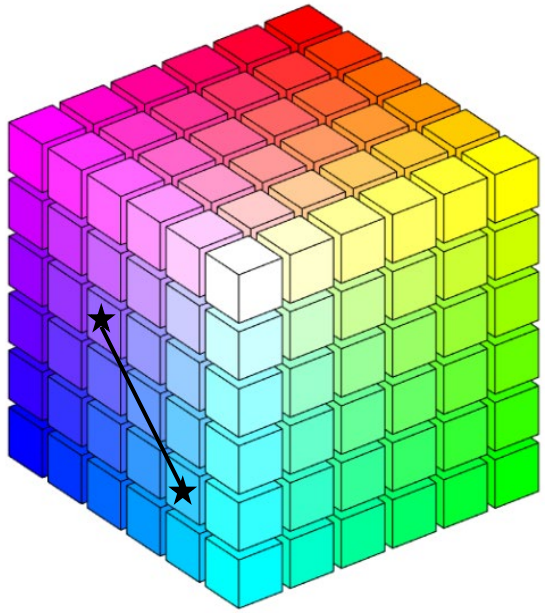


C= 50% M= 20% Y= 0%

$$distance = \sqrt{(C1 - C2)^2 + (M1 - M2)^2 + (Y1 - Y2)^2}$$

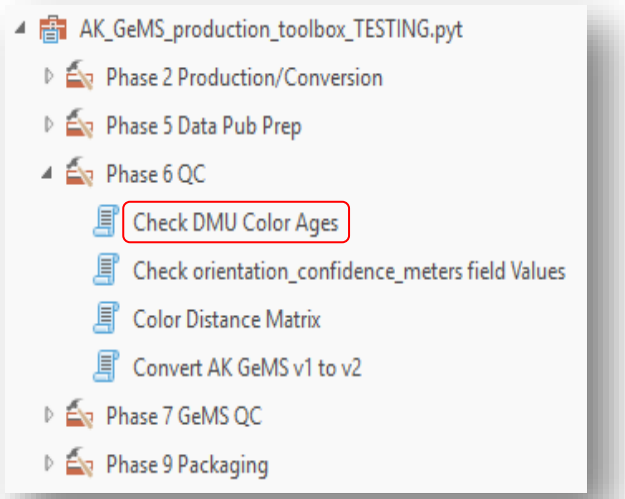
$$d = \sqrt{(30 - 50)^2 + (40 - 20)^2 + (0 - 0)^2}$$

$$d = 28.3$$



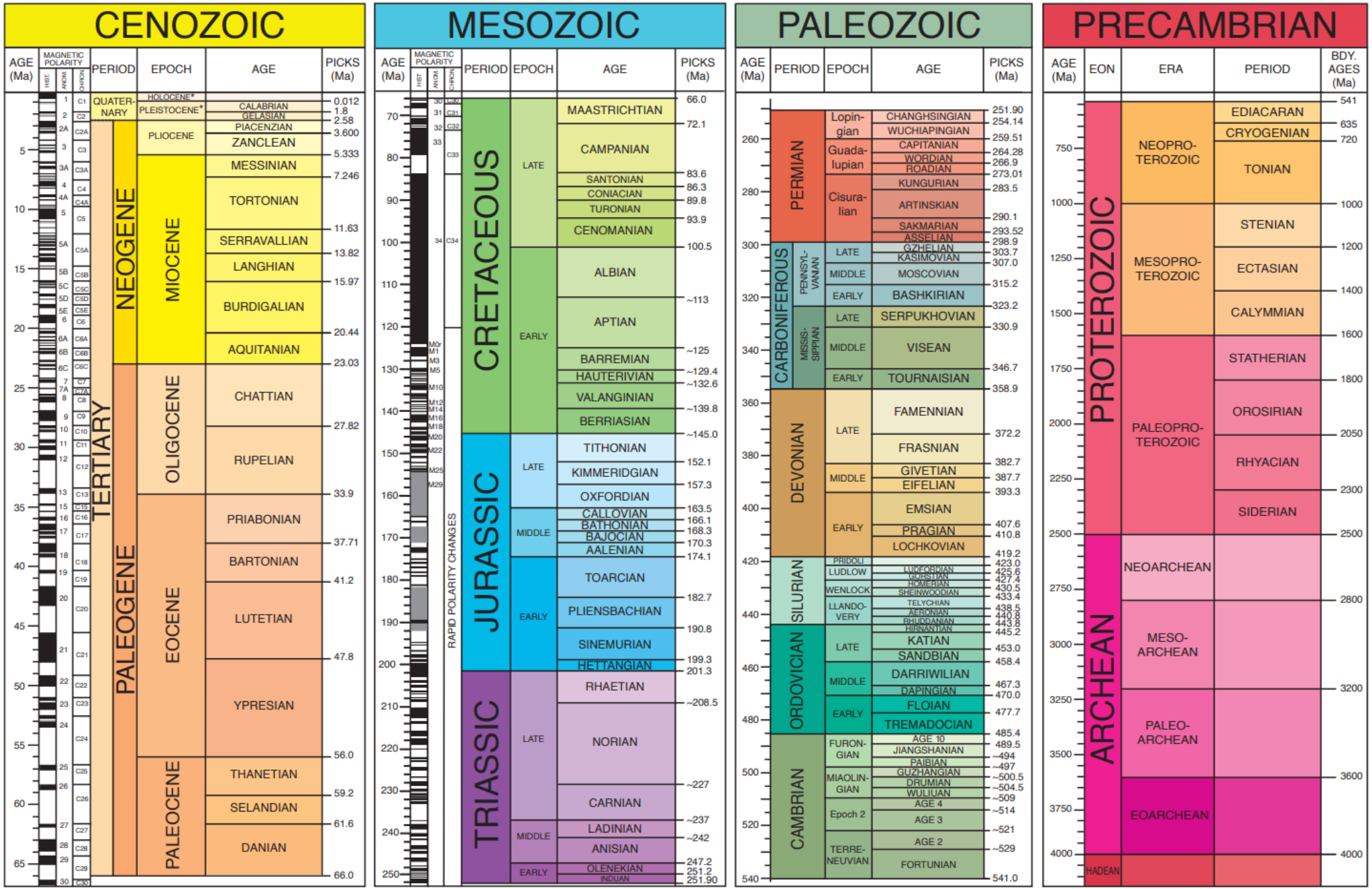
Check DMU Color Ages Tool

A	B	C	D	E	F	G
Map Unit	Age Oldest	Age Youngest	Style Age	Match Status	Distance	Symbol
Qb	Quaternary	Quaternary	Igneous; Volcanic	MATCH	0	0XX0
Ds	Devonian	Devonian	Mississippian	MISMATCH	1	6500
Dm	Devonian	Devonian	Mississippian	MISMATCH	1	2200
EKs	Cretaceous	Cretaceous	Quaternary	MISMATCH	3	0000
LKg	Cretaceous	Cretaceous	Igneous; Volcanic	MATCH	0	0X30
DOg	Devonian	Ordovician	Silurian	MATCH	0	4600
Omg	Ordovician	Ordovician	Cretaceous	MISMATCH	9	63X0
DOx	Devonian	Ordovician	Ordovician	MATCH	0	0420
DOi	Devonian	Ordovician	Permian	MISMATCH	4	6200
DOms	Devonian	Ordovician	Igneous; Volcanic	MISMATCH		0XA0
DOm	Devonian	Ordovician	Permian	MISMATCH	4	2000
DOq	Devonian	Ordovician	Ordovician	MATCH	0	07A0
DOqs	Devonian	Ordovician	Igneous; Volcanic	MISMATCH		0X70
DOsq	Devonian	Ordovician	Cambrian	MISMATCH	1	0750
DOs	Devonian	Ordovician	Cambrian	MISMATCH	1	0AA0
Osg	Ordovician	Ordovician	Jurassic	MISMATCH	8	A020
Oi	Ordovician	Ordovician	Jurassic	MISMATCH	8	6040
DOu	Devonian	Precambrian	Precambrian; Proterozoic; Archean	MATCH	0	2A20
PzPh	Paleozoic	Proterozoic	Precambrian; Proterozoic; Archean	MISMATCH		4770
PzPa	Paleozoic	Proterozoic	Precambrian; Proterozoic; Archean	MISMATCH		3450
--- OVERALL ACCURACY REPORT ---						
Total Units	20					
Matches	6					
Mismatches	14					



Results

1. Percent of map unit record whose age matches
2. How far off mismatched records DMU ages are from style file age


CENOZOIC
AGE (Ma)
MAGNETIC POLARITY
HIST
ANOM
CHRON
PERIOD
EPOCH
AGE
PICKS (Ma)
QUATER-NARY
NEOGENE
PALEOGENE
TERTIARY
HOLOCENE*
PLEISTOCENE*
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
CALABRIAN
GELASIAN
PIACENZIAN
ZANCLEAN
MESSINIAN
TORTONIAN
SERRAVALLIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
CHATTIAN
RUPELIAN
PRIABONIAN
BARTONIAN
LUTETIAN
YPRESIAN
THANETIAN
SELANDIAN
DANIAN
0.012
1.8
2.58
3.600
5.333
7.246
11.63
13.82
15.97
20.44
23.03
27.82
33.9
37.71
41.2
47.8
56.0
59.2
61.6
66.0
MESOZOIC
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BATHONIAN
BAJOCIAN
AALENIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
RHAETIAN
NORIAN
CARNIAN
LADINIAN
ANISIAN
OLENEKIAN
INDUAN
CRETACEOUS
JURASSIC
TRIASSIC
LATE
EARLY
MIDDLE
RAPID POLARITY CHANGES
66.0
72.1
83.6
86.3
89.8
93.9
100.5
~113
~125
~129.4
~132.6
~139.8
~145.0
152.1
157.3
163.5
166.1
168.3
170.3
174.1
182.7
190.8
199.3
201.3
~208.5
~227
~237
~242
247.2
251.2
251.90
PALEOZOIC
PERMIAN
CARBONIFEROUS
PENNSYL-VANIAN
MISSIS-SIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
Lopin-gian
Guada-lupian
Cisura-lian
PRIDOLI
LUDLOW
WENLOCK
LLANDO-VERY
FURON-GIAN
MIAOLIN-GIAN
Epoch 2
TERRE-NEUVIAN
CHANGHSINGIAN
WUCHIAPINGIAN
CAPITANIAN
WORDIAN
ROADIAN
KUNGURIAN
ARTINSKIAN
SAKMARIAN
ASSELIAN
GZHELIAN
KASIMOVIAN
MOSCOVIAN
BASHKIRIAN
SERPUKHOVIAN
VISEAN
TOURNAISIAN
FAMENNIAN
FRASNIAN
GIVETIAN
EIFELIAN
EMSIAN
PRAGIAN
LOCHKOVIAN
LUDFORDIAN
GORSTIAN
HOMERIAN
SHEINWOODIAN
TELYCHIAN
AERONIAN
RHUDDANIAN
HIRNANTIAN
KATIAN
SANDBIAN
DARRIWILIAN
DAPINGIAN
FLOIAN
TREMADOCIAN
AGE 10
JIANGSHANIAN
PAIBIAN
GUZHANGIAN
DRUMIAN
WULIUAN
AGE 4
AGE 3
AGE 2
FORTUNIAN
251.90
254.14
259.51
264.28
266.9
273.01
283.5
290.1
293.52
298.9
303.7
307.0
315.2
323.2
330.9
346.7
358.9
372.2
382.7
387.7
393.3
407.6
410.8
419.2
423.0
425.6
427.4
430.5
433.4
438.5
440.8
443.8
445.2
453.0
458.4
467.3
470.0
477.7
485.4
489.5
~494
~497
~500.5
~504.5
~509
~514
~521
~529
541.0
PRECAMBRIAN
AGE (Ma)
EON
ERA
PERIOD
BDY. AGES (Ma)
PROTEROZOIC
ARCHEAN
HADEAN
NEOPRO-TEROZOIC
MESOPRO-TEROZOIC
PALEOPRO-TEROZOIC
NEOARCHEAN
MESO-ARCHEAN
PALEO-ARCHEAN
EOARCHEAN
EDIACARAN
CRYOGENIAN
TONIAN
STENIAN
ECTASIAN
CALYMMIAN
STATHERIAN
OROSIRIAN
RHYACIAN
SIDERIAN
541
635
720
1000
1200
1400
1600
1800
2050
2300
2500
2800
3200
3600
4000

Standardize DMU Ages

Suggested Colors for Geologic Maps

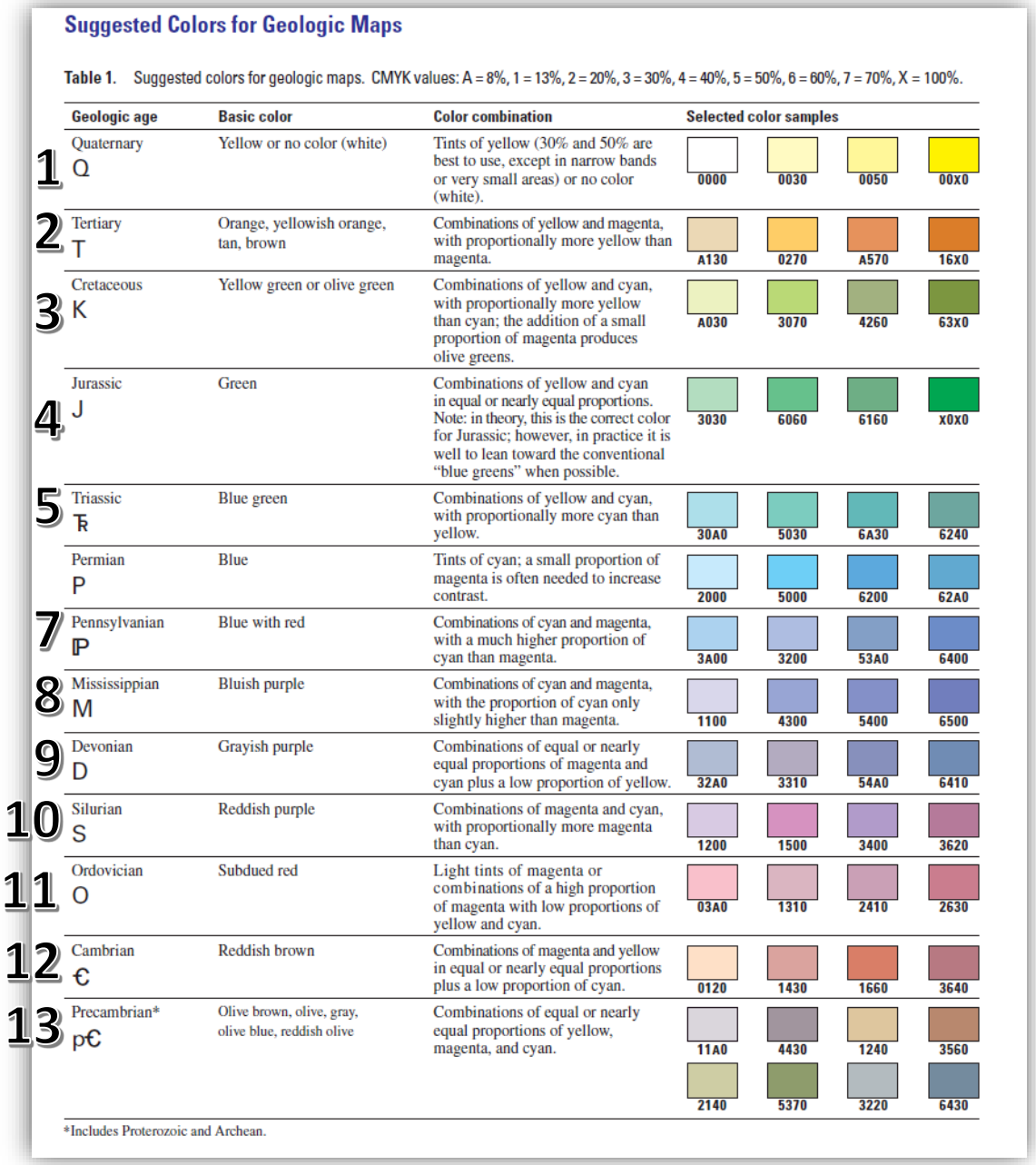
Table 1. Suggested colors for geologic maps. CMYK values: A = 8%, 1 = 13%, 2 = 20%, 3 = 30%, 4 = 40%, 5 = 50%, 6 = 60%, 7 = 70%, X = 100%.

Geologic age	Basic color	Color combination	Selected color samples
Quaternary Q	Yellow or no color (white)	Tints of yellow (30% and 50% are best to use, except in narrow bands or very small areas) or no color (white).	0000 0030 0050 00X0
Tertiary T	Orange, yellowish orange, tan, brown	Combinations of yellow and magenta, with proportionally more yellow than magenta.	A130 0270 A570 16X0
Cretaceous K	Yellow green or olive green	Combinations of yellow and cyan, with proportionally more yellow than cyan; the addition of a small proportion of magenta produces olive greens.	A030 3070 4260 63X0
Jurassic J	Green	Combinations of yellow and cyan in equal or nearly equal proportions. Note: in theory, this is the correct color for Jurassic; however, in practice it is well to lean toward the conventional "blue greens" when possible.	3030 6060 6160 X0X0
Triassic Ŧ	Blue green	Combinations of yellow and cyan, with proportionally more cyan than yellow.	30A0 5030 6A30 6240
Permian P	Blue	Tints of cyan; a small proportion of magenta is often needed to increase contrast.	2000 5000 6200 62A0
Pennsylvanian ℙ	Blue with red	Combinations of cyan and magenta, with a much higher proportion of cyan than magenta.	3A00 3200 53A0 6400
Mississippian M	Bluish purple	Combinations of cyan and magenta, with the proportion of cyan only slightly higher than magenta.	1100 4300 5400 6500
Devonian D	Grayish purple	Combinations of equal or nearly equal proportions of magenta and cyan plus a low proportion of yellow.	32A0 3310 54A0 6410
Silurian S	Reddish purple	Combinations of magenta and cyan, with proportionally more magenta than cyan.	1200 1500 3400 3620
Ordovician O	Subdued red	Light tints of magenta or combinations of a high proportion of magenta with low proportions of yellow and cyan.	03A0 1310 2410 2630
Cambrian €	Reddish brown	Combinations of magenta and yellow in equal or nearly equal proportions plus a low proportion of cyan.	0120 1430 1660 3640
Precambrian* p€	Olive brown, olive, gray, olive blue, reddish olive	Combinations of equal or nearly equal proportions of yellow, magenta, and cyan.	11A0 4430 1240 3560 2140 5370 3220 6430

*Includes Proterozoic and Archean.

	map_unit *	symbol	age_label	age_oldest	age_youngest
6	Jdap	0X00	Jurassic	Jurassic	Jurassic
7	pMm	6540	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
8	Jdfi	0X00	Jurassic	Jurassic	Jurassic
9	Jcp	0X00	Jurassic	Jurassic	Jurassic
10	Tg	04X0	Tertiary	Tertiary	Tertiary
11	pMg	4450	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
12	pMq	4660	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
13	pMoq	4760	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
14	MJdf	0X00	Jurassic or pre-Mississippian	Jurassic or pre-Mississi...	Jurassic or pre-Mississi...
15	JKdl	0X00	Jurassic or younger	Jurassic or younger	Jurassic or younger
16	uPzst	3330	upper Paleozoic	upper Paleozoic	upper Paleozoic
17	uPzv	5550	upper Paleozoic	upper Paleozoic	upper Paleozoic
18	Jdhg	0X00	Jurassic	Jurassic	Jurassic
19	uPzl	6550	upper Paleozoic	upper Paleozoic	upper Paleozoic
20	MDag	3760	Mississippian to Devonian	Devonian	Mississippian
21	Jc	0320	Jurassic	Jurassic	Jurassic
22	MDog	3750	Mississippian to Devonian	Devonian	Mississippian
23	Jt	2X40	Jurassic	Jurassic	Jurassic
24	pMqgs	2240	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
25	pMaf	2320	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
26	pMam	4540	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
27	pMa	3320	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
28	pMsg	3460	Pre-Mississippian	Pre-Mississippian	Pre-Mississippian
29	uPzmg	6550	upper Paleozoic	upper Paleozoic	upper Paleozoic
30	Jg	0X00	Jurassic?	Jurassic?	Jurassic?
31	TJcp	7XX0	Jurassic to Tertiary?	Jurassic	Tertiary?

- Clean up DMU ages: lower cases, ?s, adjectives
- Map all potential ages to FGDC Ages



Suggested Colors for Geologic Maps

Table 1. Suggested colors for geologic maps. CMYK values: A = 8%, 1 = 13%, 2 = 20%, 3 = 30%, 4 = 40%, 5 = 50%, 6 = 60%, 7 = 70%, X = 100%.

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13	Precambrian* pЄ	Olive brown, olive, gray, olive blue, reddish olive	Combinations of equal or nearly equal proportions of yellow, magenta, and cyan.	11A0 4430 1240 3560 2140 5370 3220 6430

*Includes Proterozoic and Archean.

Symbol: A640

FGDC Standard Symbol Age: Cambrian

Name	Type	Category
A640	Polygon symbol	Cambrian

Description of Map Units Symbol Age: Tertiary

map_unit *	symbol	age_label	age_oldest	age_youngest
Tg	A640	Tertiary	Tertiary	Tertiary

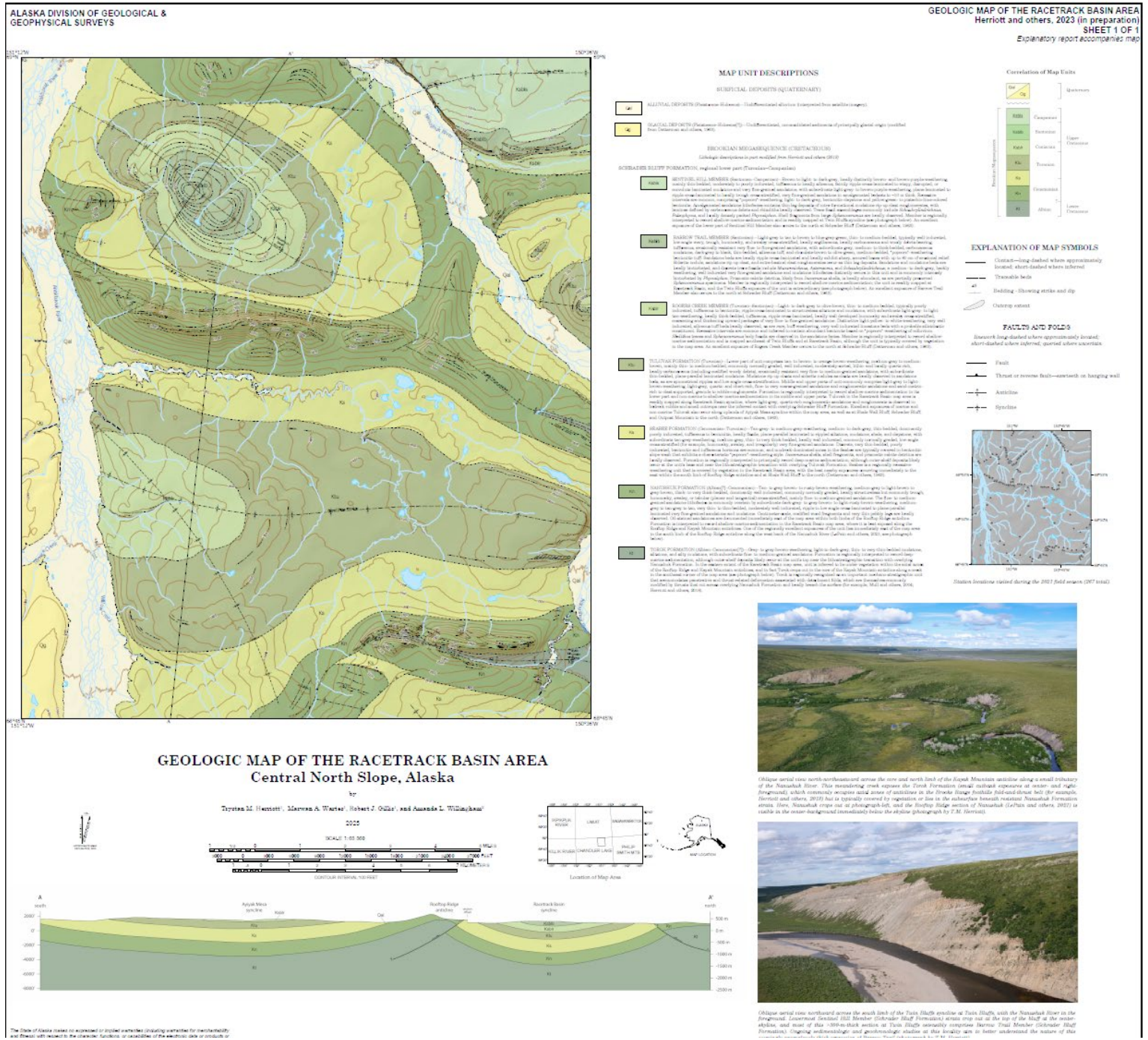
= Age Mismatch of 10

Lower Legibility, High Age Accuracy

Color Distance Assessment

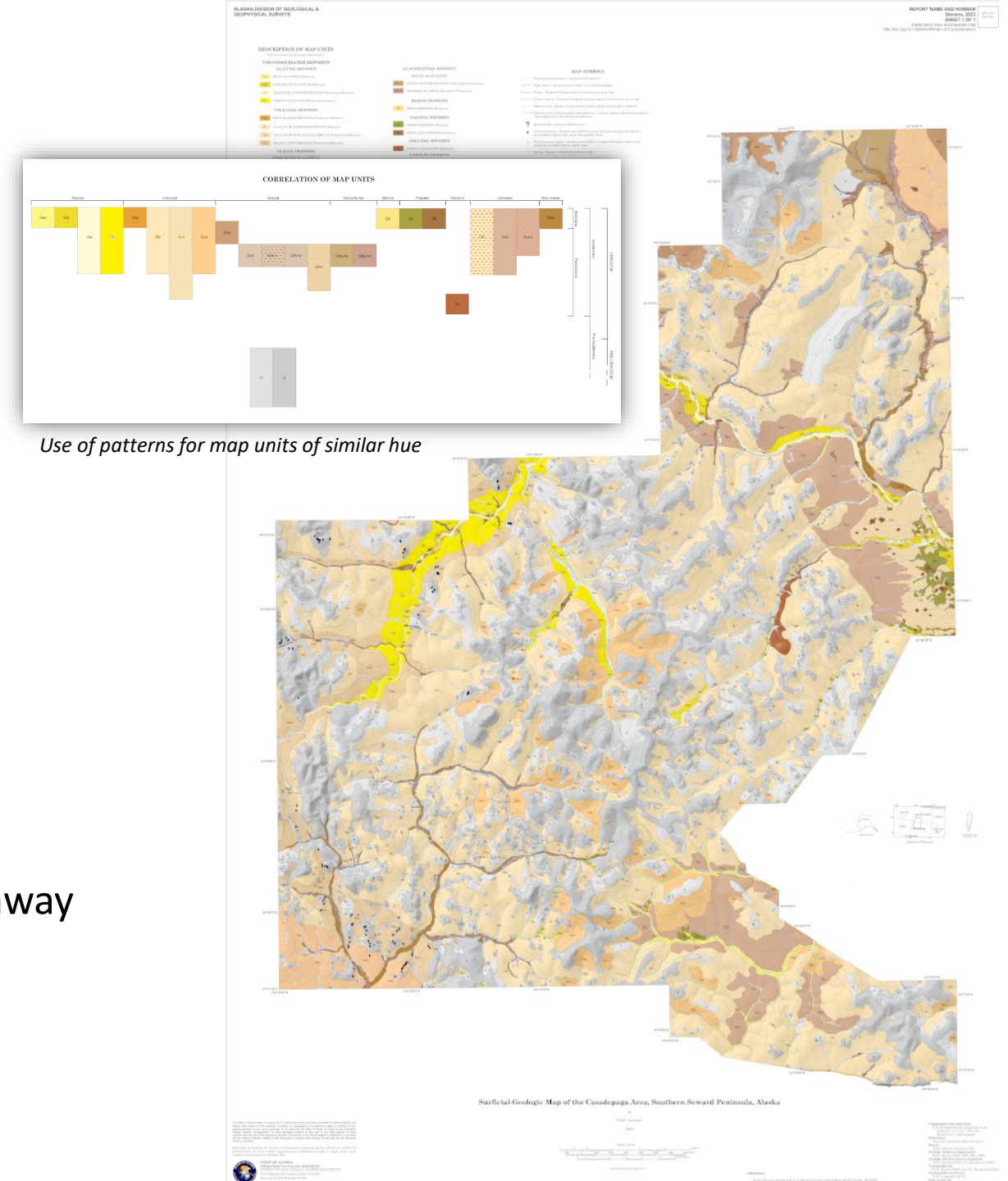
- Average distance 25.9
- 3 Great
- 3 Good
- 2 Bad

- Color Age Assesment
  - 10/10 Match



High Legibility, Low Age Accuracy

- Color Distance Assessment
  - Average Distance= 53.5
  - 24/24 Great
- Color Age Assessment
  - Correct Age: 3/25 map units
  - How many adjacent: 0
  - How many completely put of whack
    - 11 map units within 3 age categories
    - 11 map units more than 13 categories away



Use of patterns for map units of similar hue

Questions?

Email: ally.steinleitner@alaska.gov

Ally Steinleitner