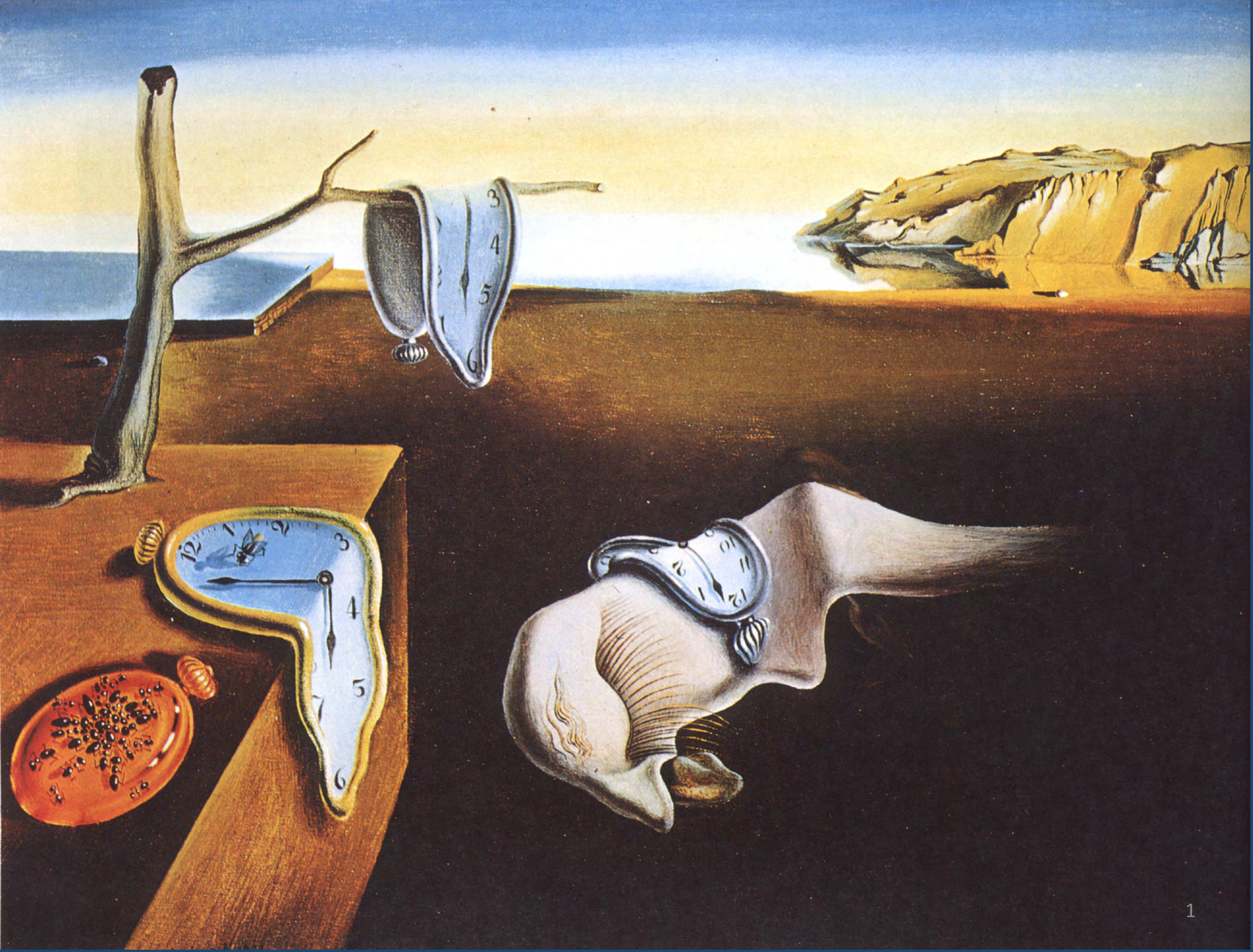
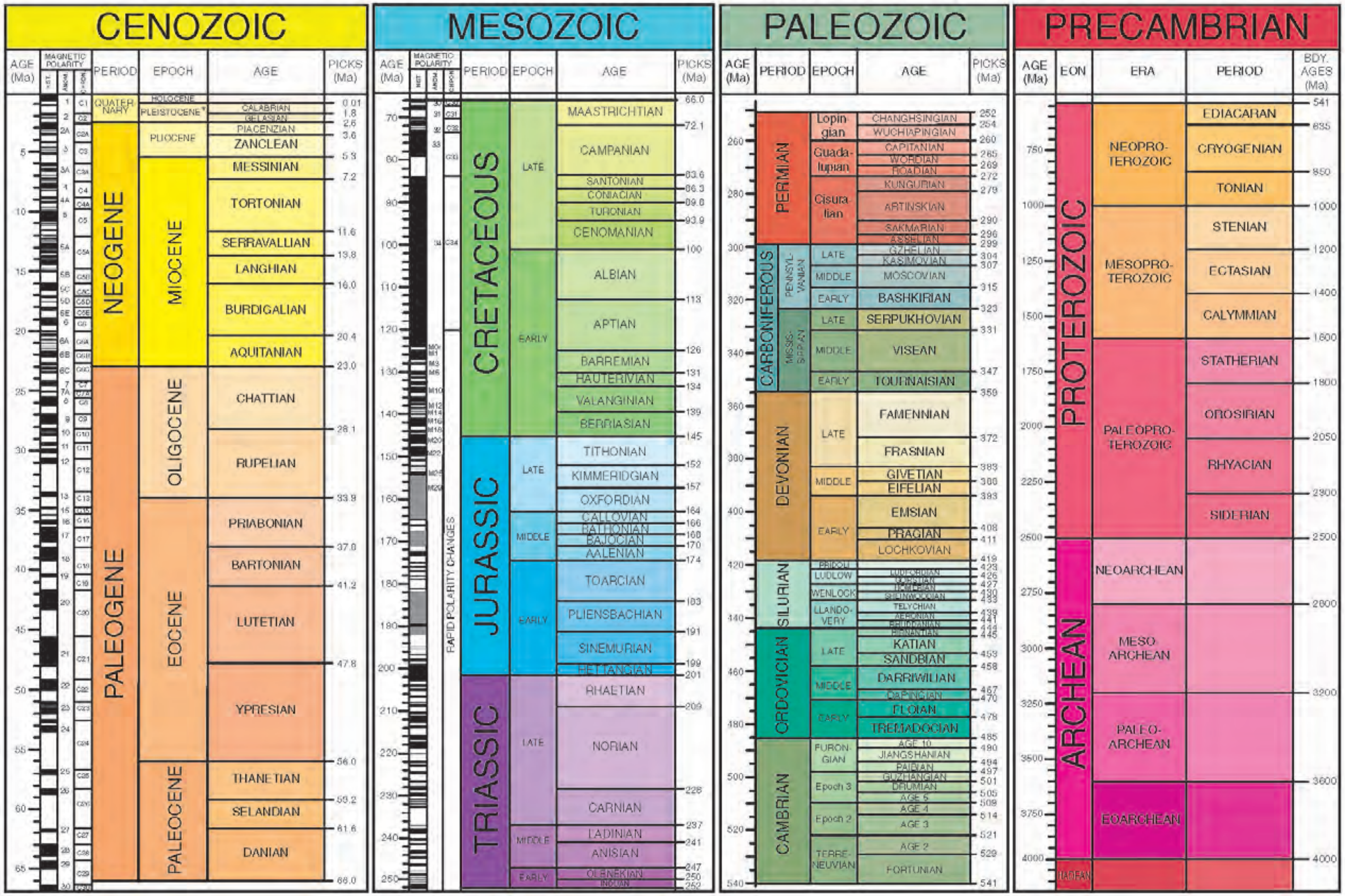


GSA GEOLOGIC TIME SCALE v. 4.0



*The Pleistocene is divided into four ages, but only two are shown here. What is shown as Calabrian is actually three ages—Calabrian from 1.8 to 0.78 Ma, Middle from 0.78 to 0.13 Ma, and Late from 0.13 to 0.01 Ma.

Walker, J.D., Geissman, J.W., Bowring, S.A., and Babcock, L.E., compilers, 2012, Geologic Time Scale v. 4.0: Geological Society of America, doi: 10.1130/2012.CTS004R3C. ©2012 The Geological Society of America.

The Cenozoic, Mesozoic, and Paleozoic are the Eras of the Phanerozoic Eon. Names of units and age boundaries follow the Gradstein et al. (2012) and Cohen et al. (2012) compilations. Age estimates and picks of boundaries are rounded to the nearest whole number (1 Ma) for the pre-Cenomanian, and rounded to one decimal place (100 ka) for the Cenomanian to Pleistocene interval. The numbered epochs and ages of the Cambrian are provisional.

REFERENCES CITED: Cohen, K.M., Finney, S., and Gibbard, P.L., 2012, International Chronostratigraphic Chart: International Commission on Stratigraphy, www.stratigraphy.org (last accessed May 2012). (Chart reproduced for the 34th International Geological Congress, Brisbane, Australia, 5–10 August 2012.)

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., et al., 2012, The Geologic Time Scale 2012: Boston, USA, Elsevier, DOI: 10.1016/B978-0-444-59425-9.00004-4.

THE GEOLOGICAL SOCIETY OF AMERICA®

Time

Relative

Order of deposition of a body of rock based on position

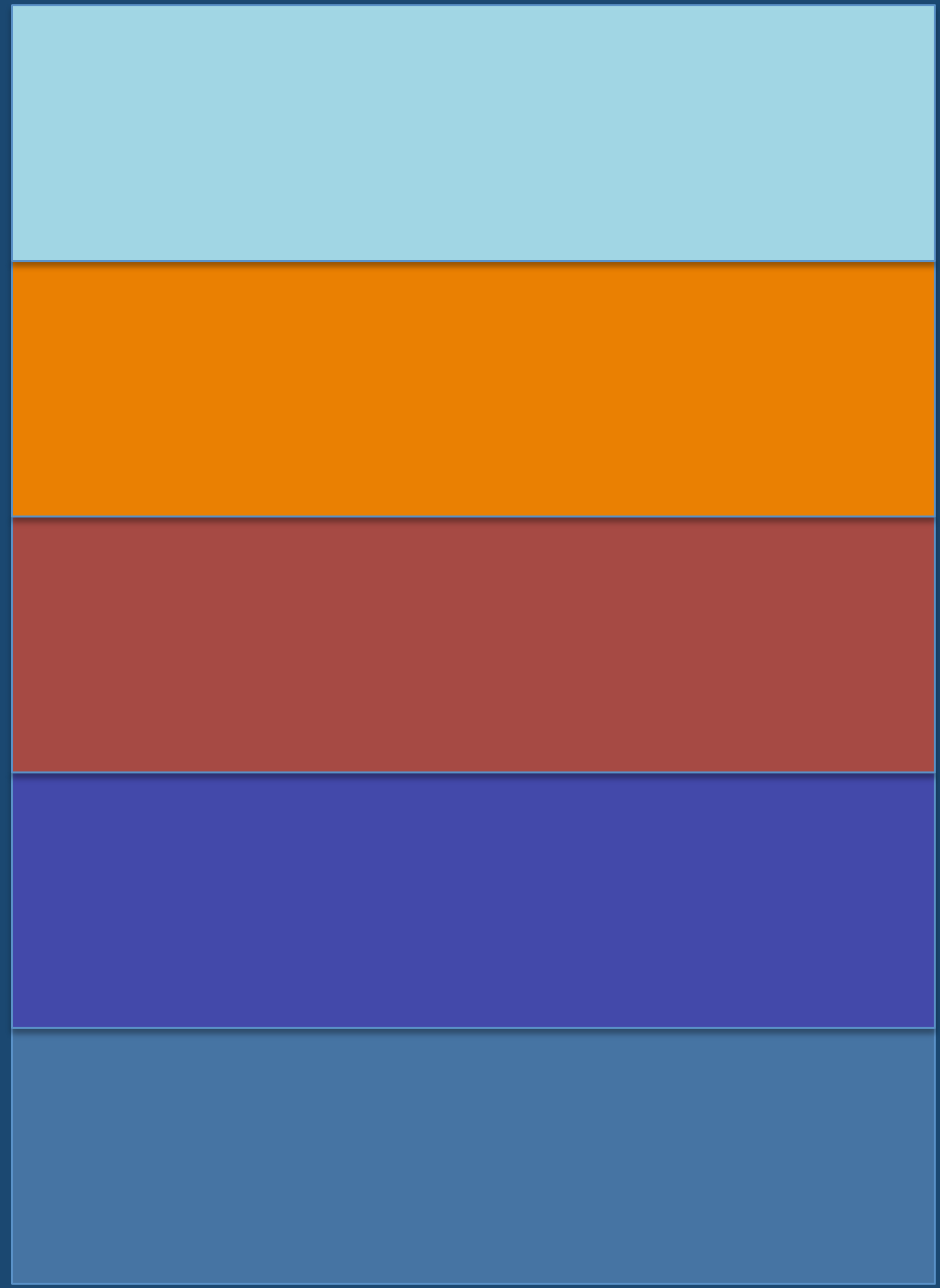
Absolute

A number representing the time a body of rock was deposited

Steno:

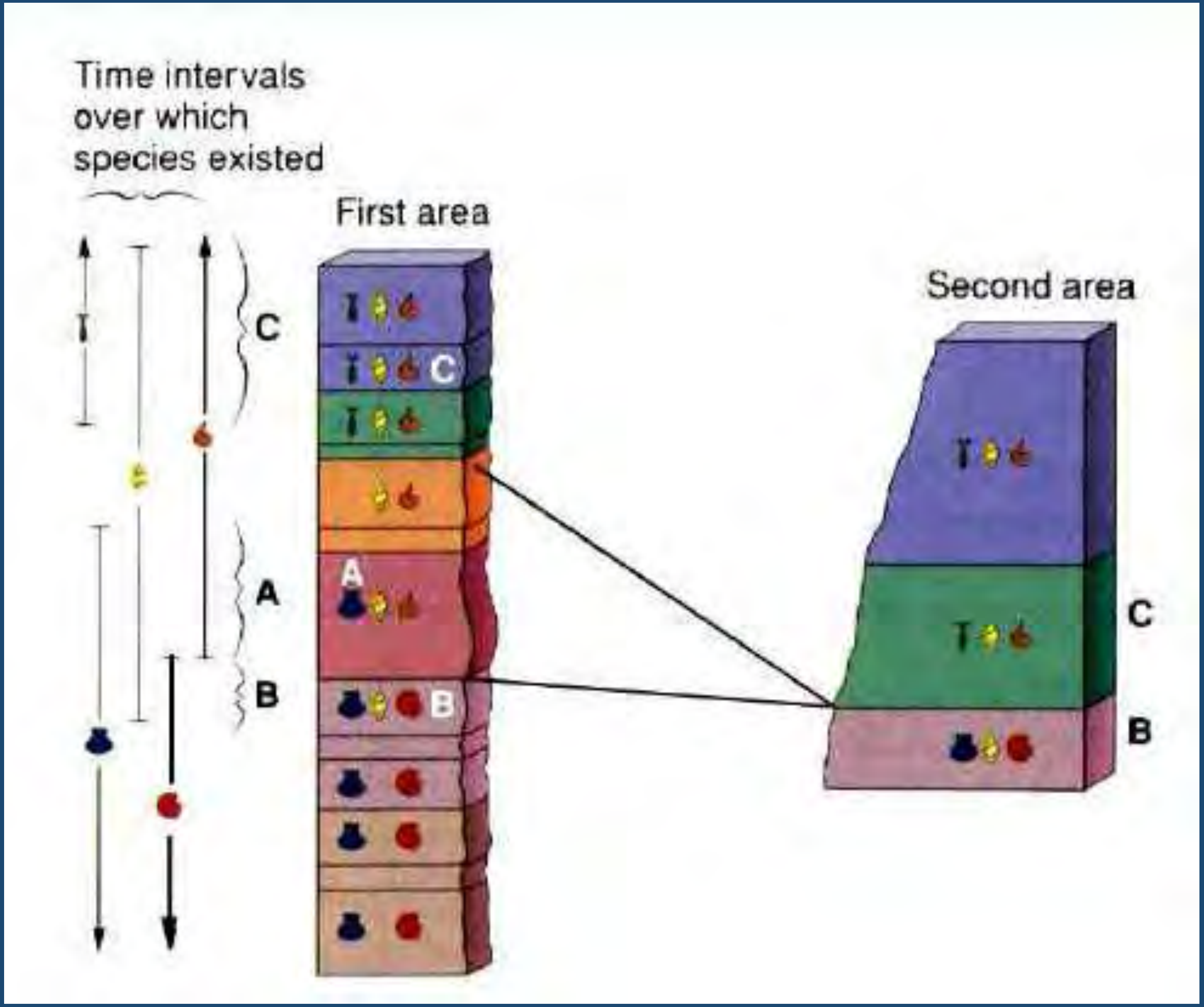
superposition

horizontality




Steno:
superposition
horizontality

Smith: fossil succession



Unconformities

Unconformities are buried surfaces of erosion or non-deposition

Nonconformity
Brahma Schist underlies Tapeats Sandstone

http://www.physci.mc.maricopa.edu/Geology/FieldTrips/ColoradoRiver/ColoradoRiver_2006_Summer/ColoradoRiver_2006_Summer_Images_1024/DSC00512a_1024c.jpg

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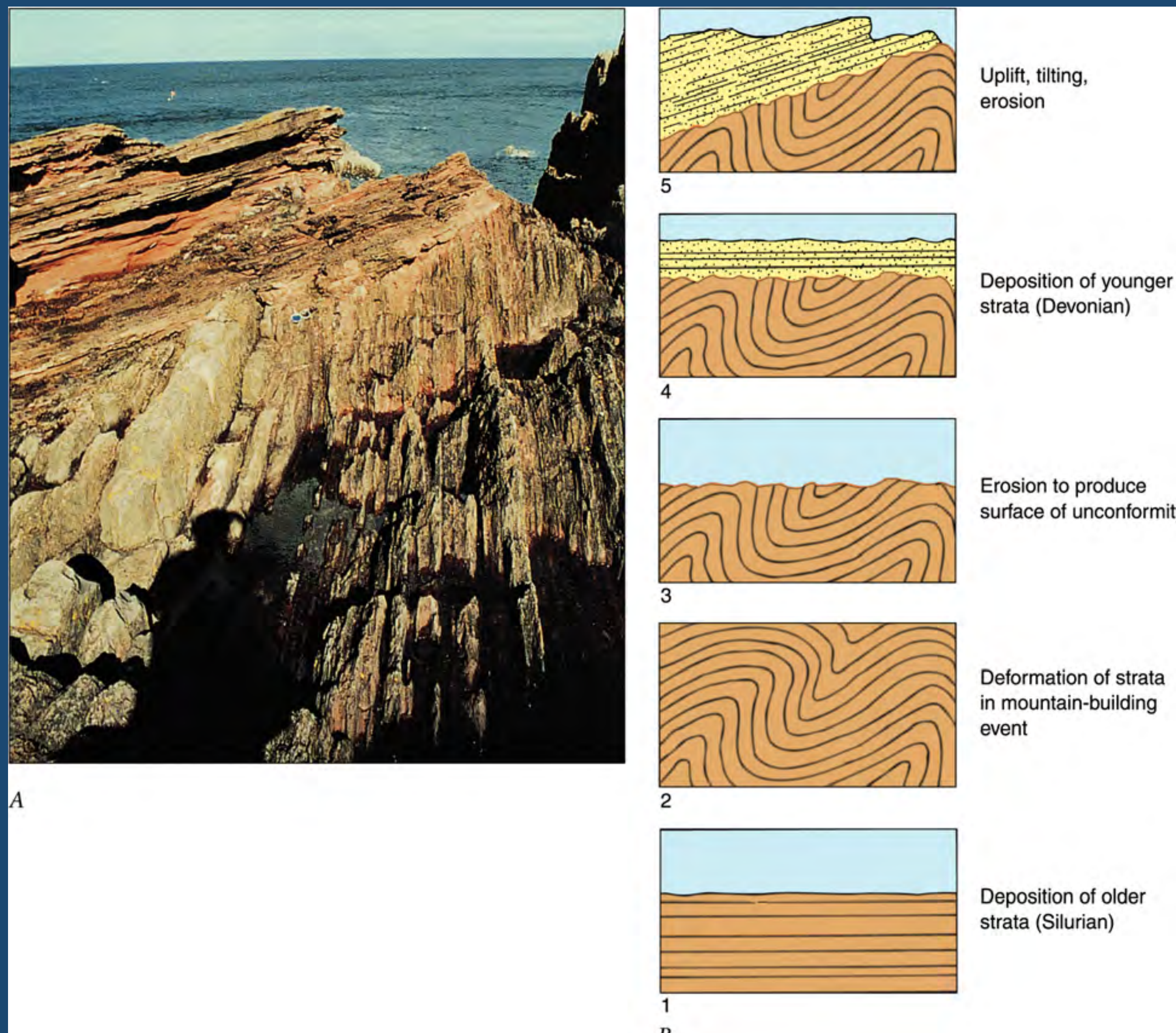
Siccar Point



Coaledo Formation (Eocene), near Cape Arago, OR

Biostratigraphy

- Biostratigraphic unit
  - Defined and characterized by their fossil content
- Stratigraphic range
  - Total vertical interval through which that species occurs in strata, from lowermost to uppermost occurrence

Biostratigraphy

- Index fossil
  - Abundant enough in the stratigraphic record to be found easily
  - Easily distinguished from other taxa
  - Geographically widespread and thus can be used to correlate rocks over a large area
  - Occurs in many kinds of sedimentary rocks and therefore can be found in many places
  - Has a narrow stratigraphic range, which allows for precise correlation if its mere presence is used to define a zone

FOSSILS…

Trilobites

Ferns

Brachiopods

Ammonites

Achaeopteryx

Seymouria

When did they live?

Long ago?

How long?

All at once?

When?

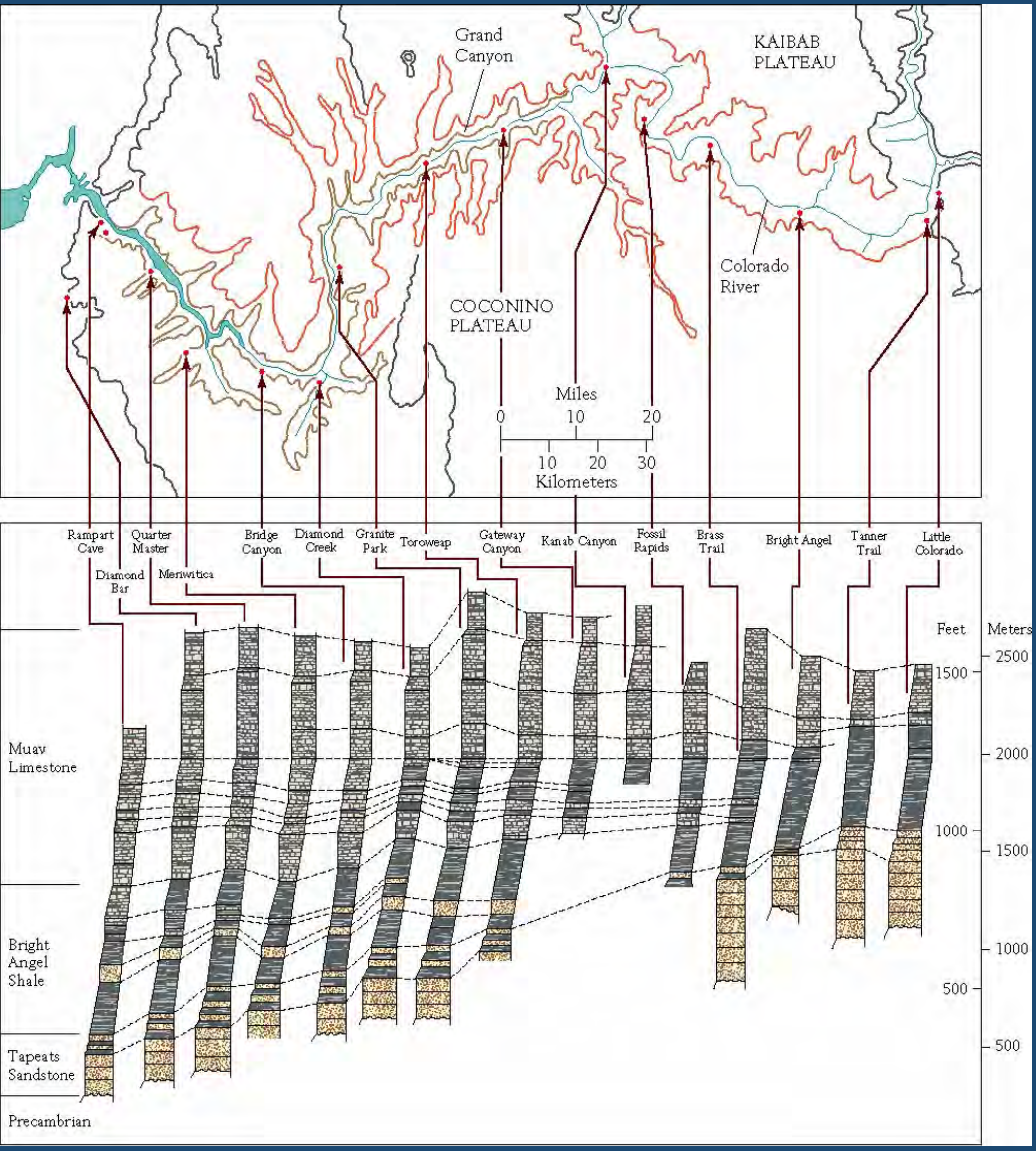
Animals of the Past: Patterns in the Fossil Record

Notice the origins… Notice the time…

Lithostratigraphy

- Subdivision of the stratigraphic record on the basis of physical or chemical characteristics of rock
- Lithostratigraphic units
  - Formation
    - Local three-dimensional bodies of rock
      - Group
      - Member
- Stratigraphic section
  - Local outcrop of a formation that displays a continuous vertical sequence
- Type section
  - Locality where the unit is well exposed, that defines the unit

Lithologic Correlation



- Cross-sections of strata
  - Establish geometric relationships
  - Interpret mode of origin

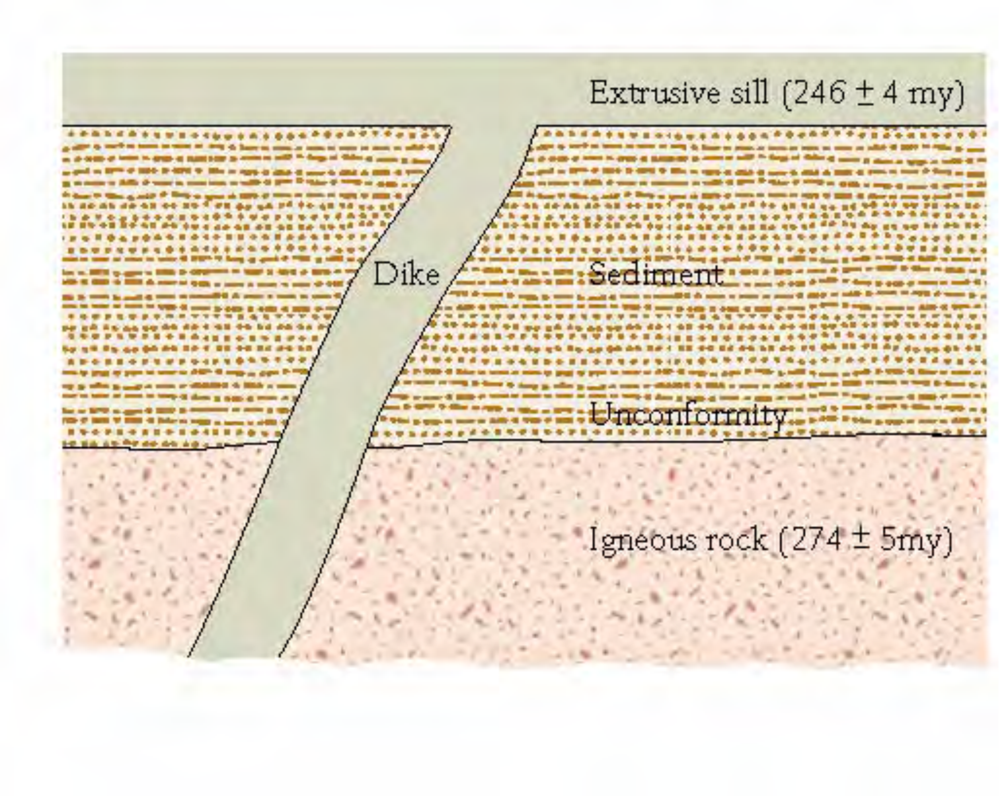
Absolute Ages

- How old is the Earth?
- 4.6 billion years (4,600,000,000 years)
- Radiometric dating (Uranium, Thorium). Mass spectrometer.

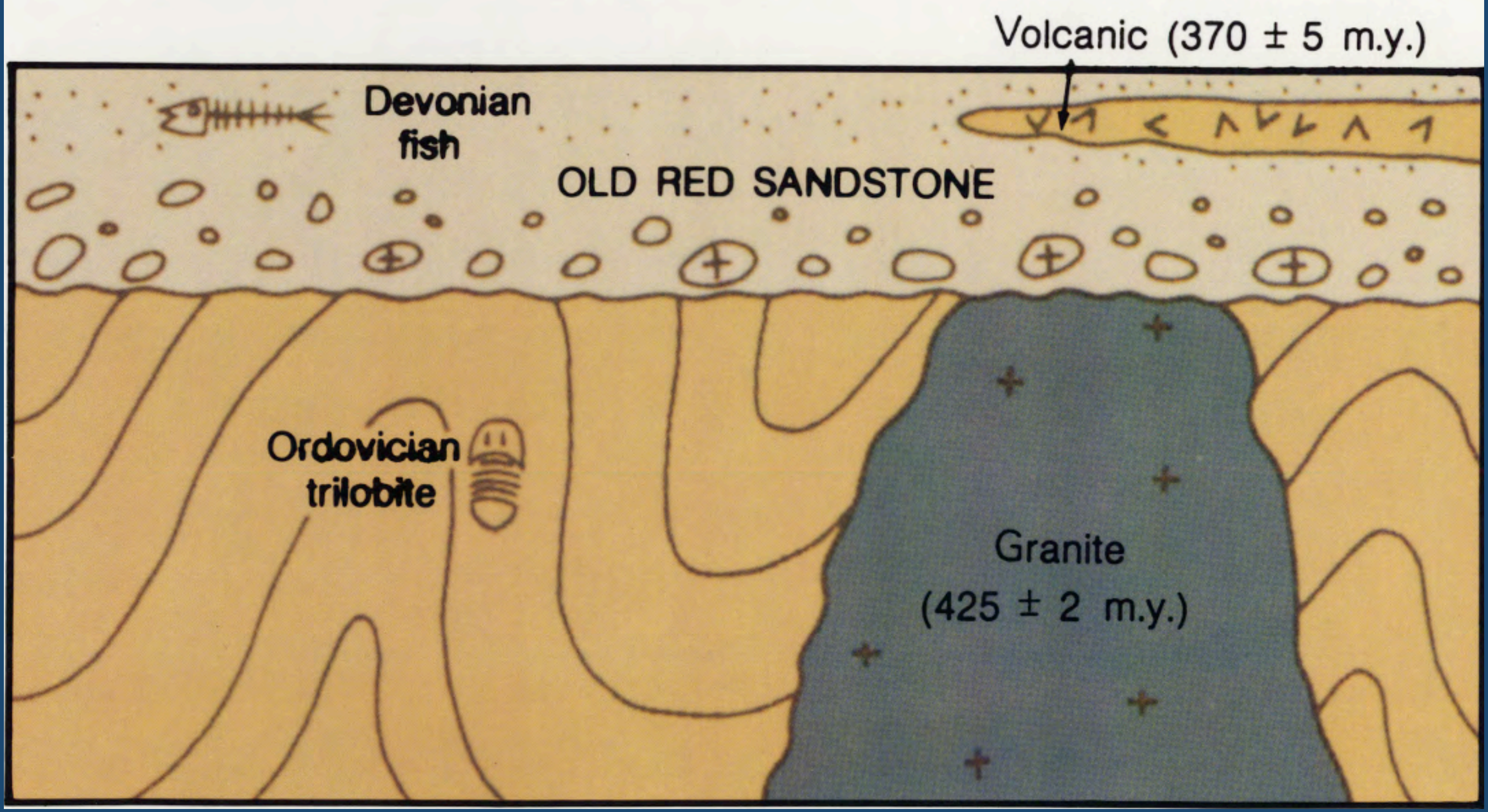
Radioactive parent isotopes and their stable daughter products

Radioactive Parent	Stable Daughter	Half Life
Potassium 40	Argon 40	1.25 billion yrs
Rubidium 87	Strontium 87	48.8 billion yrs
Thorium 232	Lead 208	14 billion years
Uranium 235	Lead 207	704 million years
Uranium 238	Lead 206	4.47 billion years
Carbon 14	Nitrogen 14	5730 years

Absolute Age



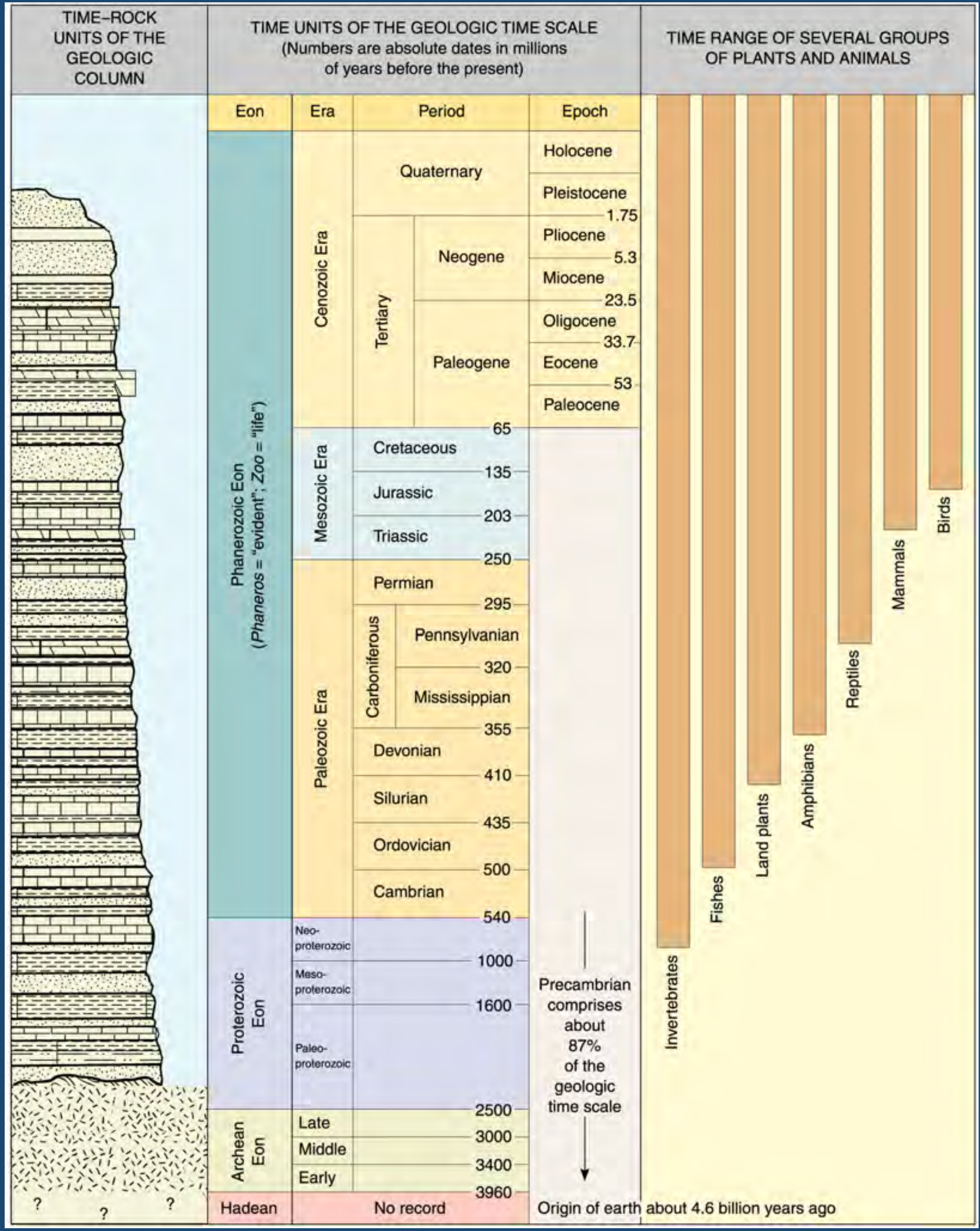
- Best candidates for most radiometric dating are igneous
  - Not necessarily useful for sediments
- Error in age estimate can be sizable



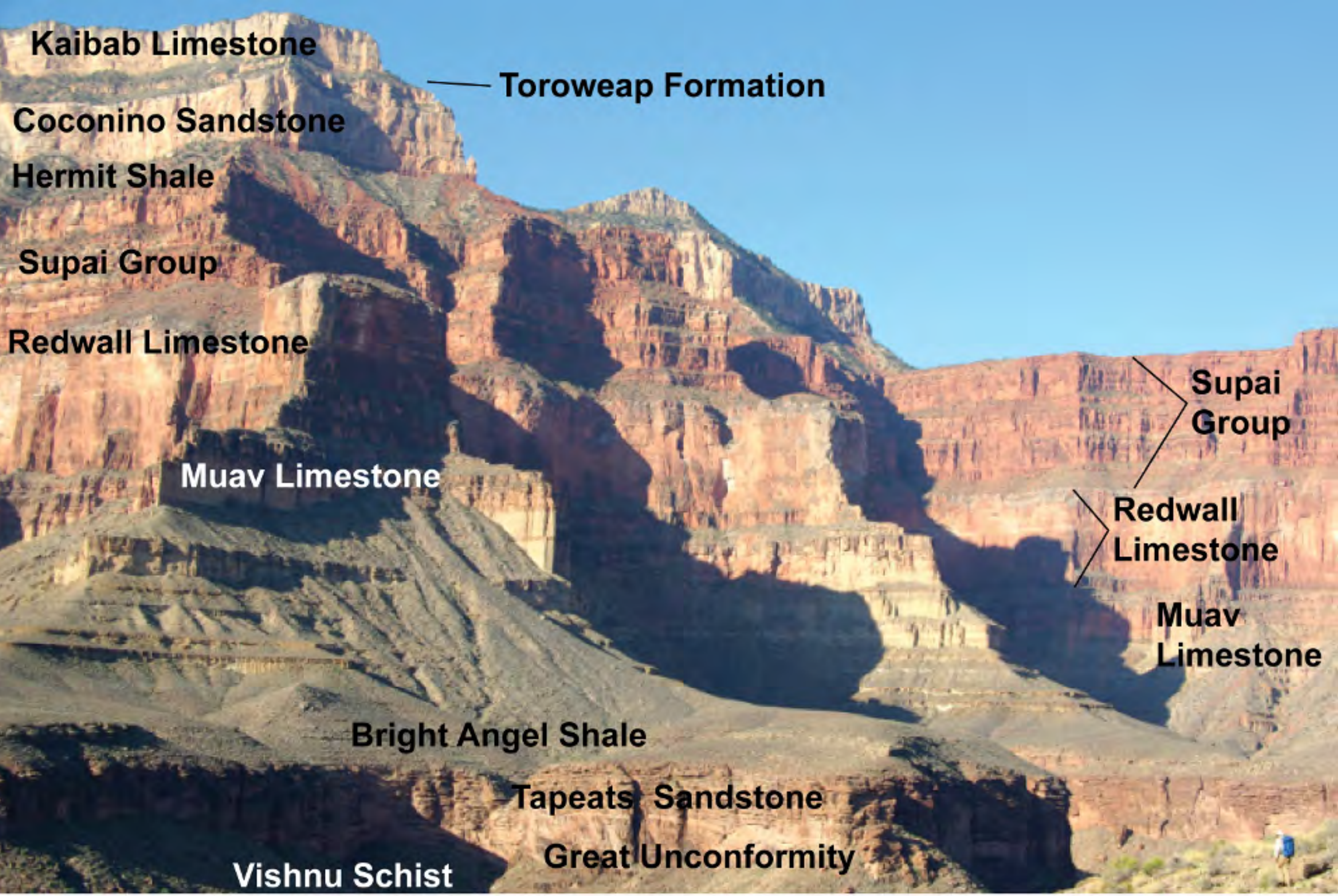
How old is the Old Red Sandstone?

a. Older than 425 myr
b. Younger than 370 myr
c. Between 425 and 370 myr
d. Have no idea

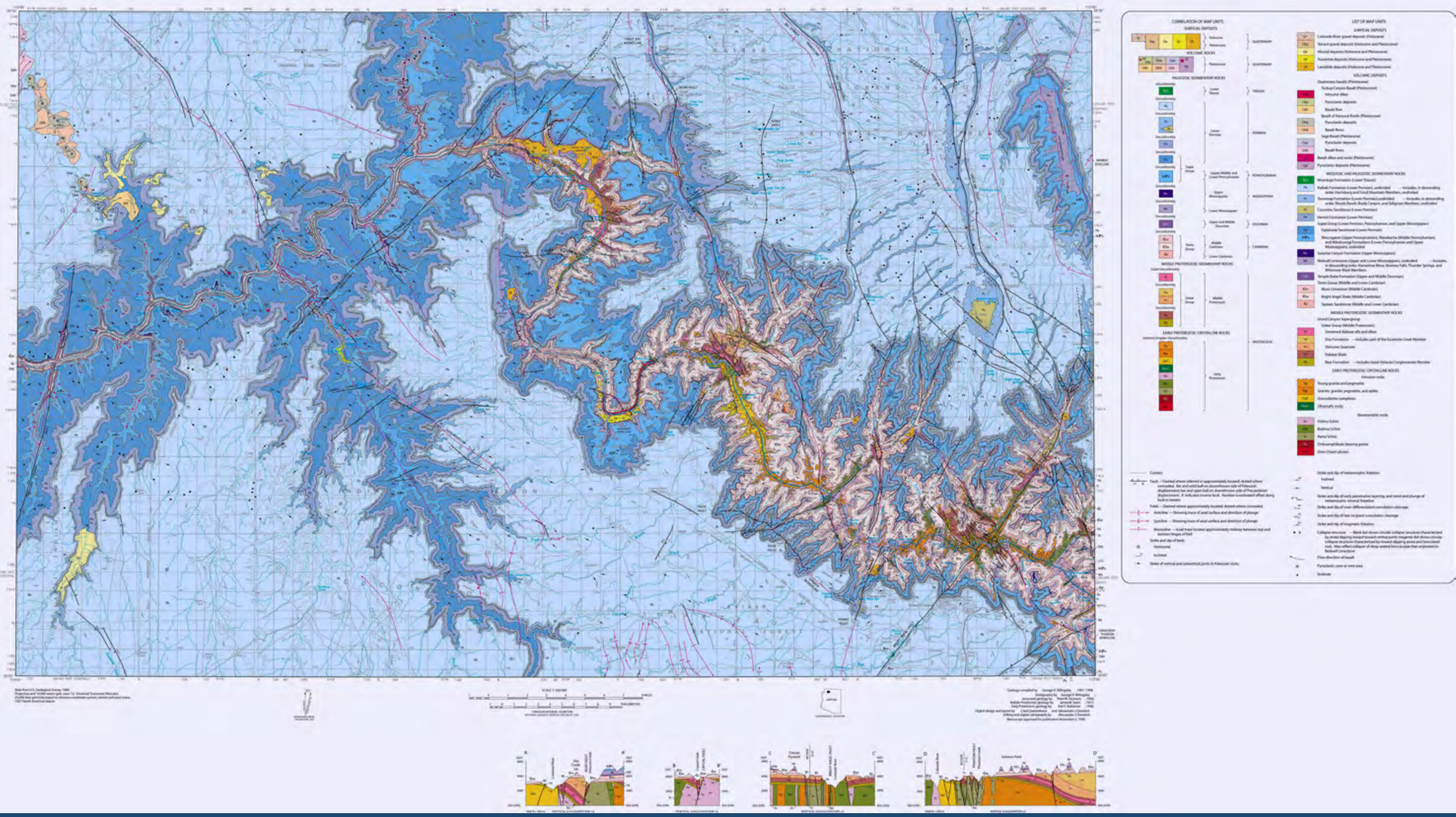
Geologic Time Scale. The age for the base of each division is in accordance with recommendations of the International Commission on Stratigraphy for the year 2000.



Geological Maps



http://www.grandcanyonguide.net/sites/default/files/geologic-cross-section-photo_1000.png



LIST OF MAP UNITS

SURFICIAL DEPOSITS

- **Qr** — Colorado River gravel deposits (Holocene)
- **Qtg** — Terrace gravel deposits (Holocene and Pleistocene)
- **Qa** — Alluvial deposits (Holocene and Pleistocene)
- **Qt** — Travertine deposits (Holocene and Pleistocene)
- **Ql** — Landslide deposits (Holocene and Pleistocene)

VOLCANIC DEPOSITS

Quaternary basalts (Pleistocene)

Tuckup Canyon Basalt (Pleistocene)

- **Qti** — Intrusive dikes
- **Qtp** — Pyroclastic deposits
- **Qtb** — Basalt flow

Basalt of Hancock Knolls (Pleistocene)

- **Qhp** — Pyroclastic deposits
- **Qhb** — Basalt flows

Sage Basalt (Pleistocene)

- **Qsp** — Pyroclastic deposits
- **Qsb** — Basalt flows
- **Qi** — Basalt dikes and necks (Pleistocene)
- **Qp** — Pyroclastic deposits (Pleistocene)

MESOZOIC AND PALEOZOIC SEDIMENTARY ROCKS

- **Ꞧm** — Moenkopi Formation (Lower Triassic)
- **Pk** — Kaibab Formation (Lower Permian), undivided —Includes, in descending order, Harrisburg and Fossil Mountain Members, undivided
- **Pt** — Toroweap Formation (Lower Permian),undivided —Includes, in descending order, Woods Ranch, Brady Canyon, and Seligman Members, undivided
- **Pc** — Coconino Sandstone (Lower Permian)
- **Ph** — Hermit Formation (Lower Permian)

Supai Group (Lower Permian, Pennsylvanian, and Upper Mississippian)

- **Pe** — Esplanade Sandstone (Lower Permian)
- **MIPu** — Wescogame (Upper Pennsylvanian), Manakacha (Middle Pennsylvanian), and Watahomigi Formations (Lower Pennsylvanian and Upper Mississippian), undivided

Mississippian), undivided

- **Ms** — Surprise Canyon Formation (Upper Mississippian)
- **Mr** — Redwall Limestone (Upper and Lower Mississippian), undivided —Include in descending order, Horseshoe Mesa, Mooney Falls, Thunder Springs, and Whitmore Wash Members
- **Dtb** — Temple Butte Formation (Upper and Middle Devonian)

Tonto Group (Middle and Lower Cambrian)

- **Ꞓm** — Muav Limestone (Middle Cambrian)
- **Ꞓba** — Bright Angel Shale (Middle Cambrian)
- **Ꞓt** — Tapeats Sandstone (Middle and Lower Cambrian)

MIDDLE PROTEROZOIC SEDIMENTARY ROCKS

Grand Canyon Supergroup

Unkar Group (Middle Proterozoic)

- **Yi** — Unnamed diabase sills and dikes
- **Yd** — Dox Formation —Includes part of the Escalante Creek Member
- **Ys** — Shinumo Quartzite
- **Yh** — Hakatai Shale
- **Yb** — Bass Formation —Includes basal Hotauta Conglomerate Member

EARLY PROTEROZOIC CRYSTALLINE ROCKS

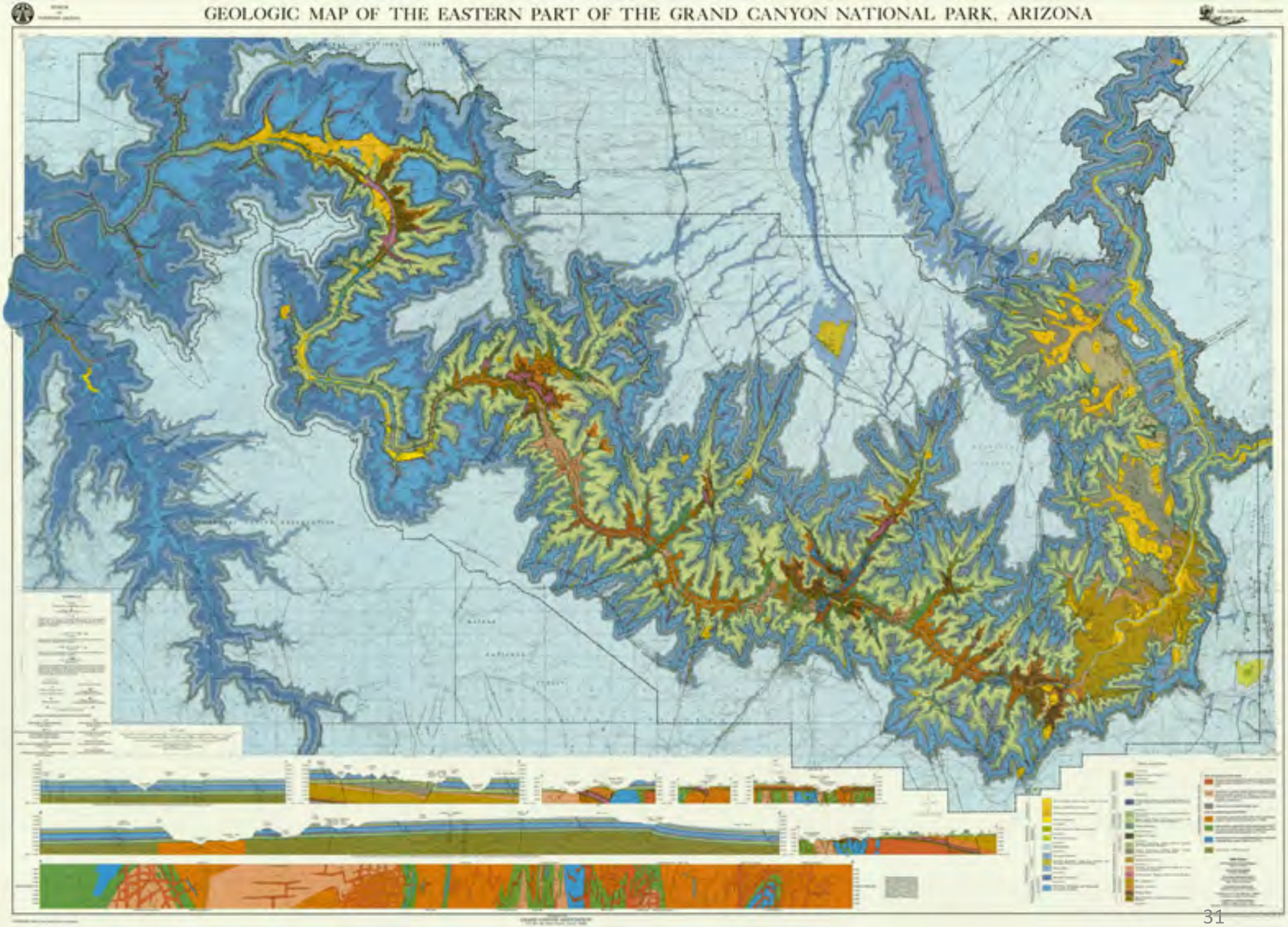
Intrusive rocks

- **Xg** — Young granite and pegmatite
- **Xgr** — Granite, granitic pegmatite, and aplite
- **Xgd** — Granodiorite complexes
- **Xum** — Ultramafic rocks

Metamorphic rocks

- **Xv** — Vishnu Schist
- **Xbr** — Brahma Schist
- **Xr** — Rama Schist
- **Xo** — Orthoamphibole-bearing gneiss
- **[illegible]** — Elves Chasm pluton


© 2014 Google
Image Landsat
Google earth
Imagery Date: 4/9/2013
36°18'19.69" N 112°40'57.56" W elev 4369 ft
eye alt 94.52 mi
N


GEOLOGIC MAP OF THE EASTERN PART OF THE GRAND CANYON NATIONAL PARK, ARIZONA


N
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Image Landsat
Google earth
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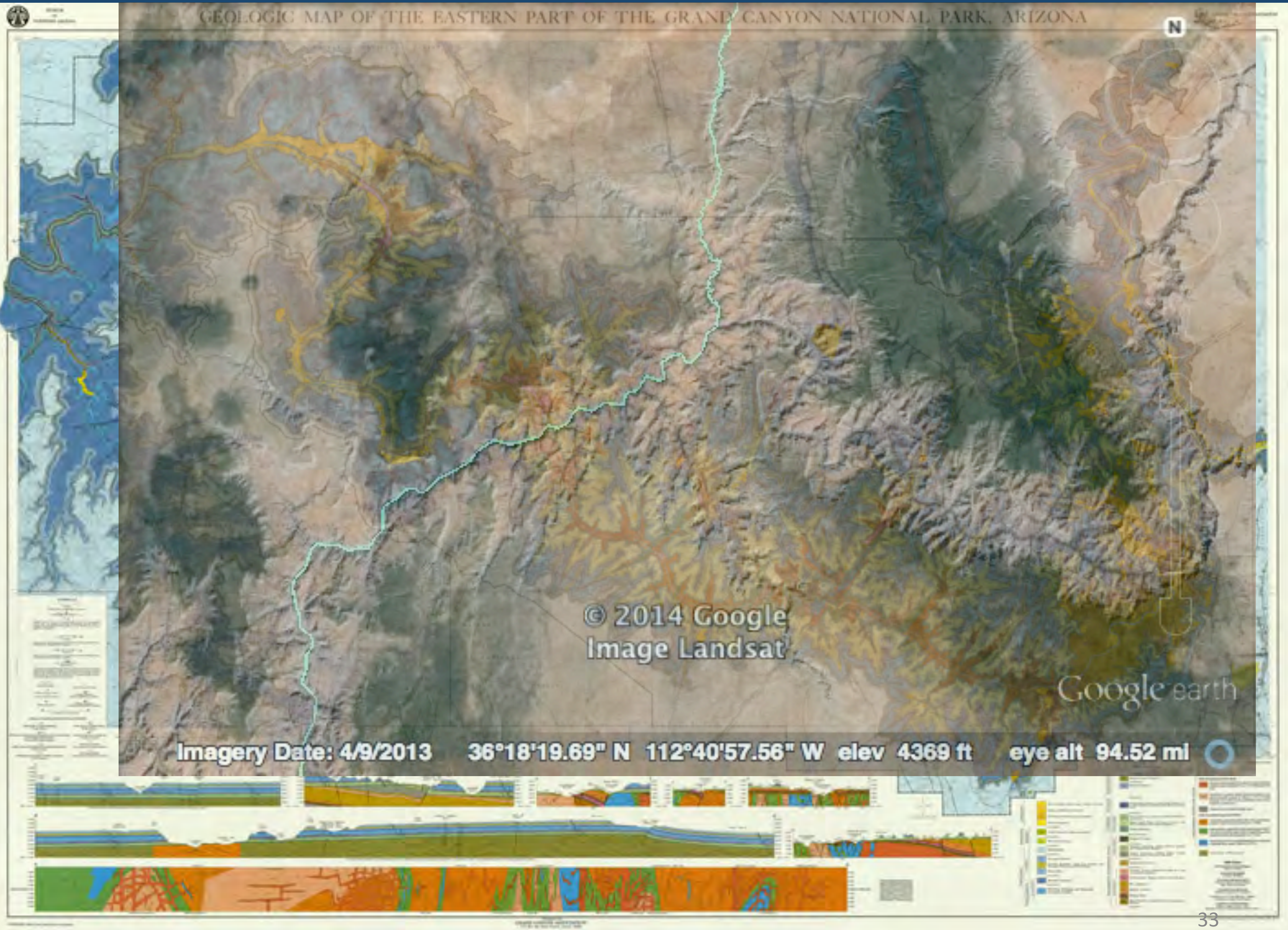
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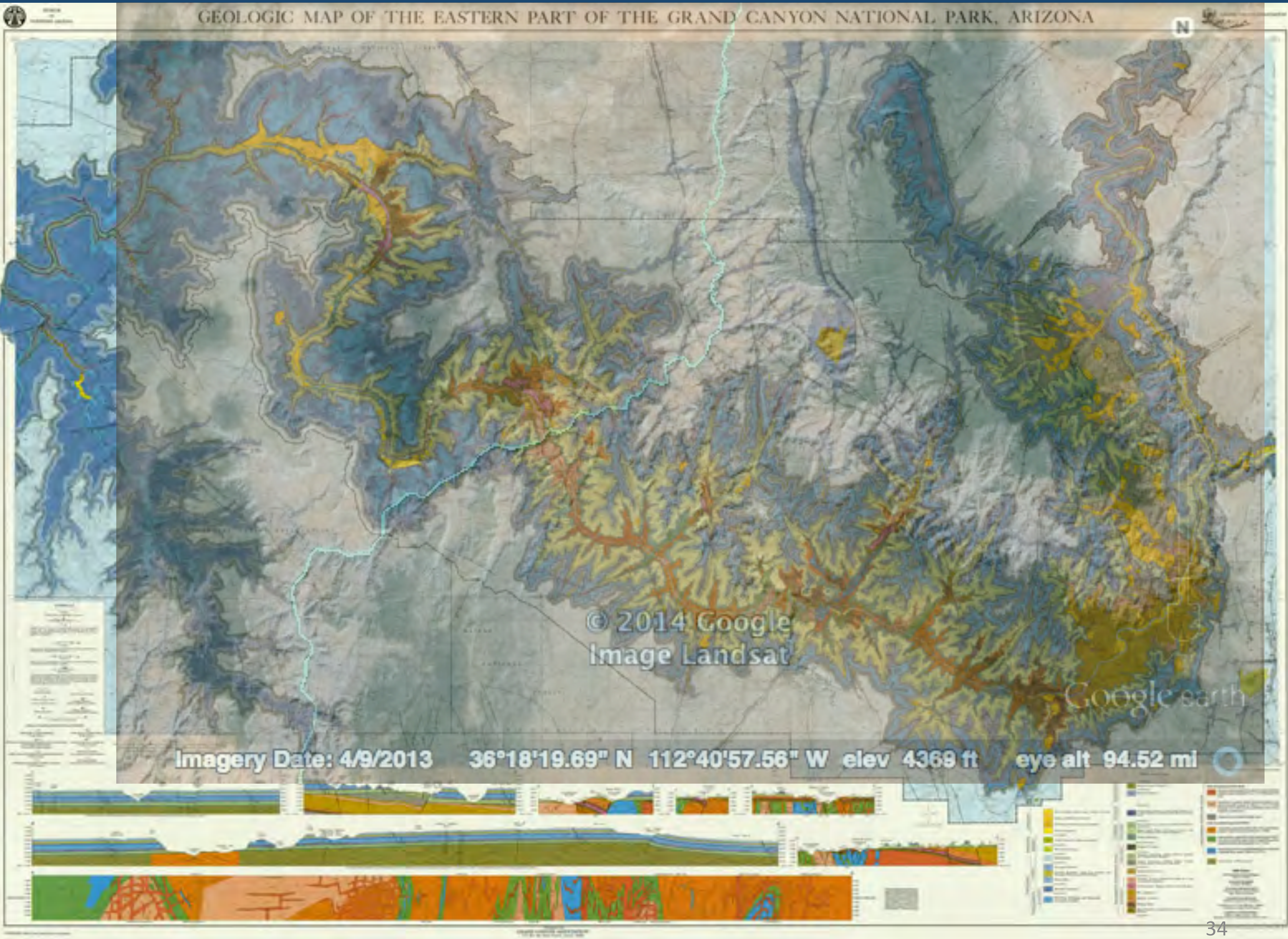

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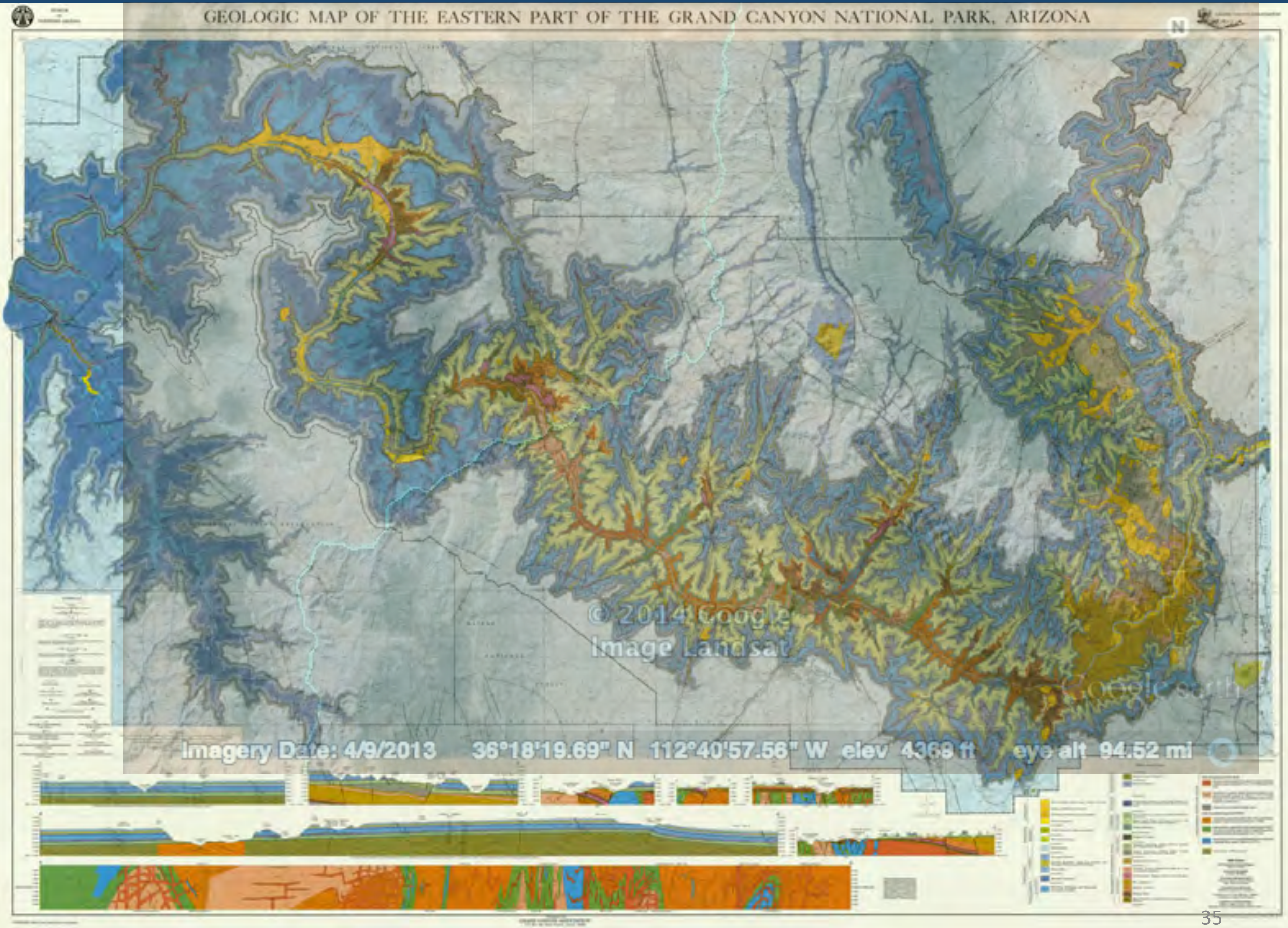

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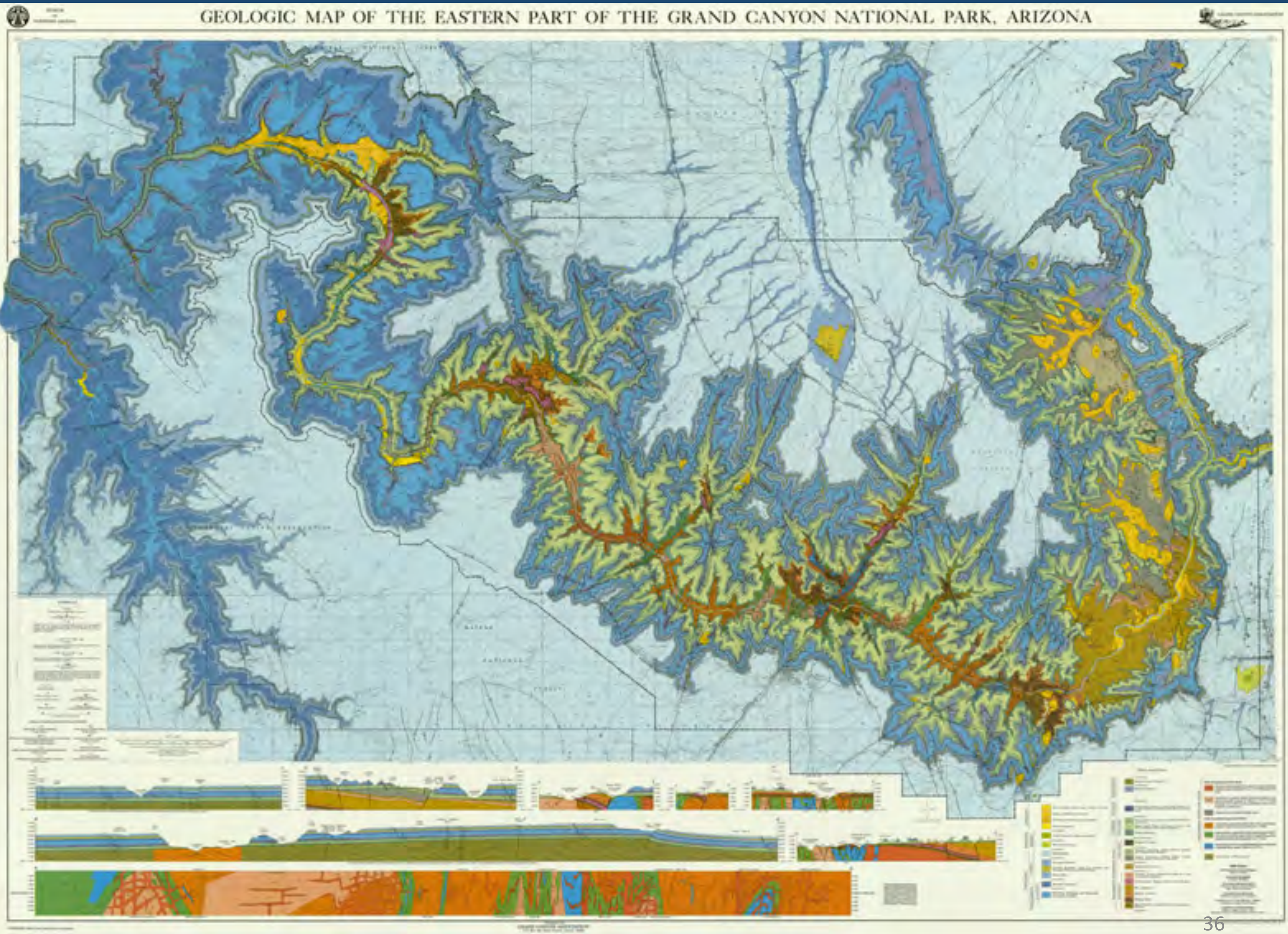
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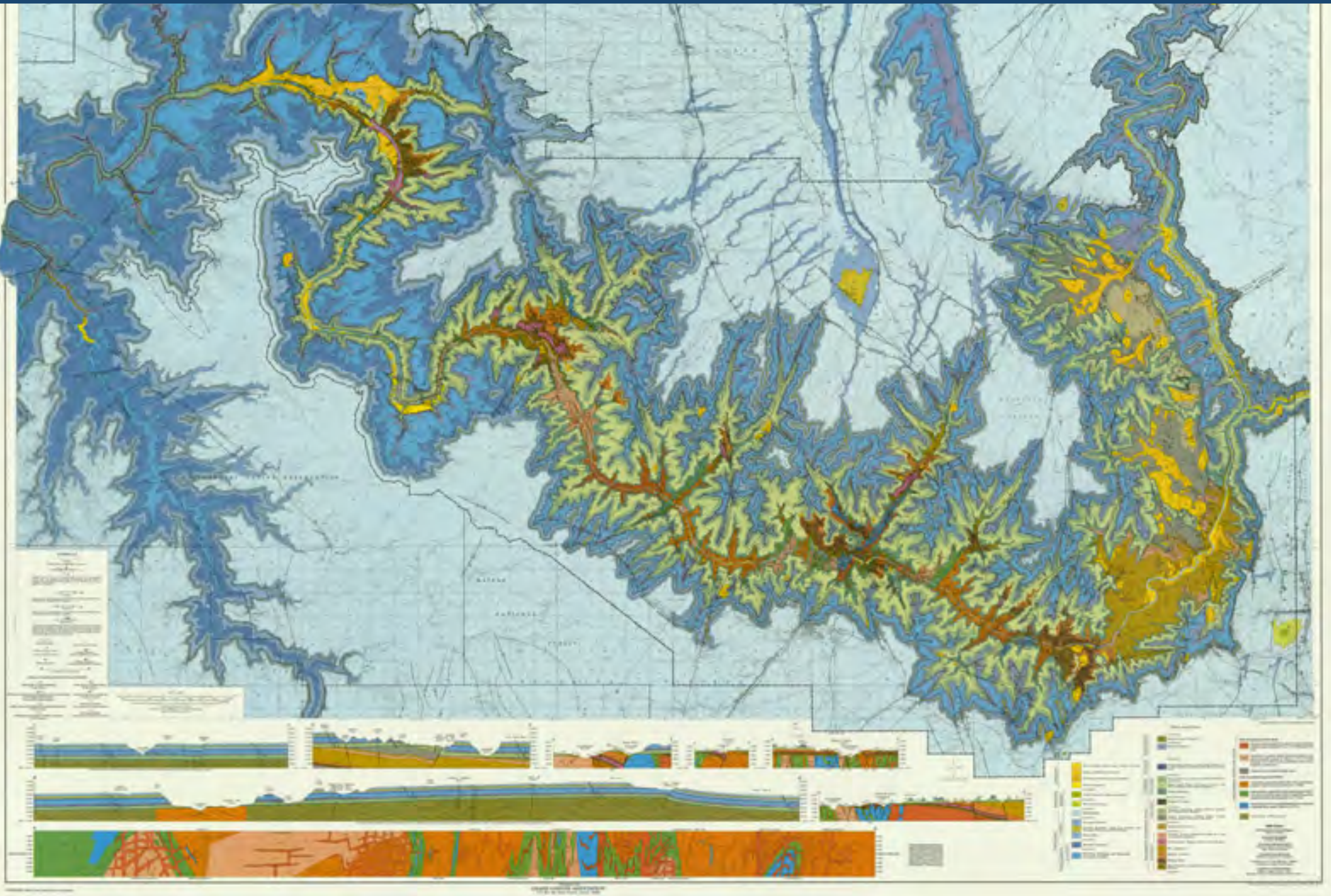
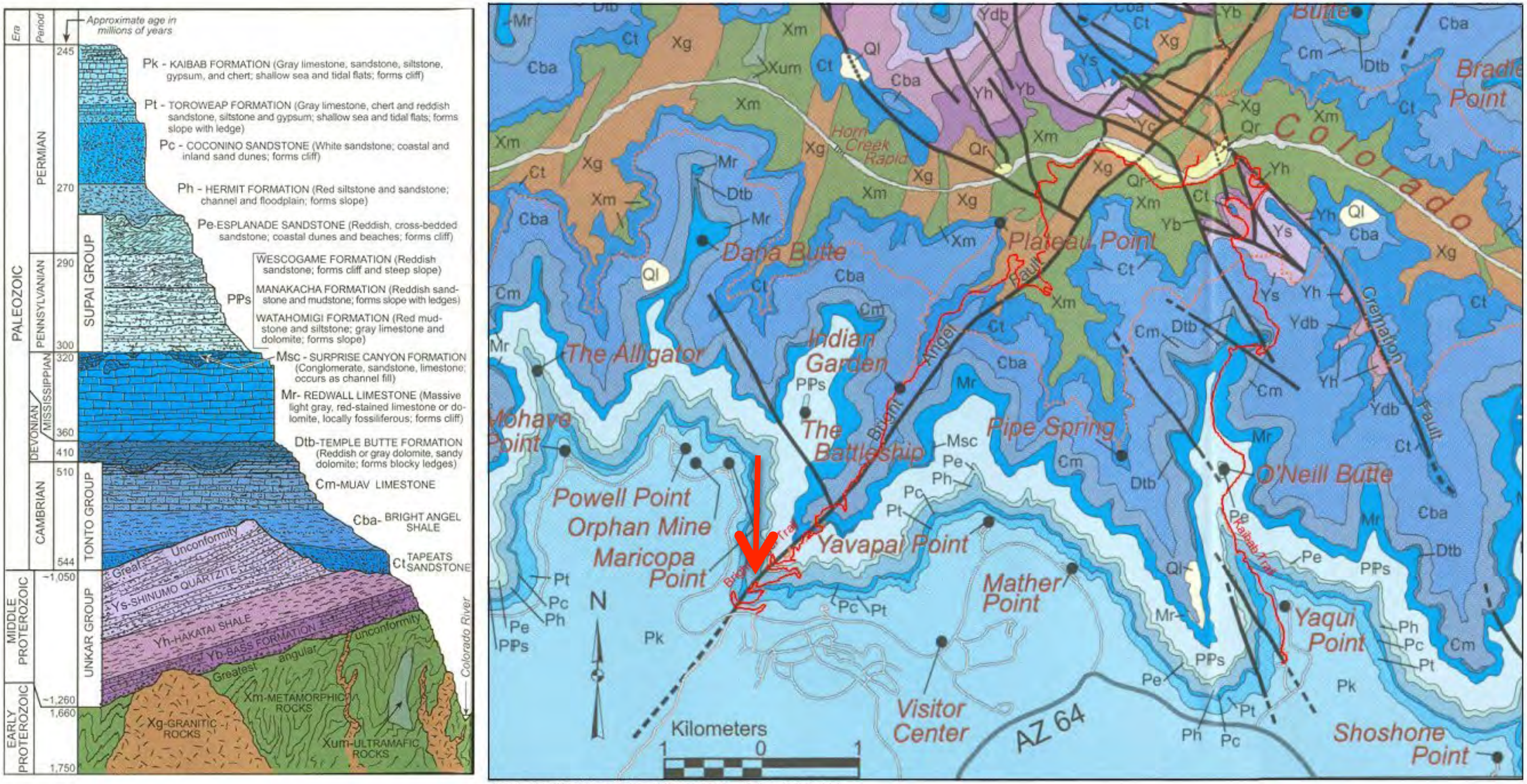
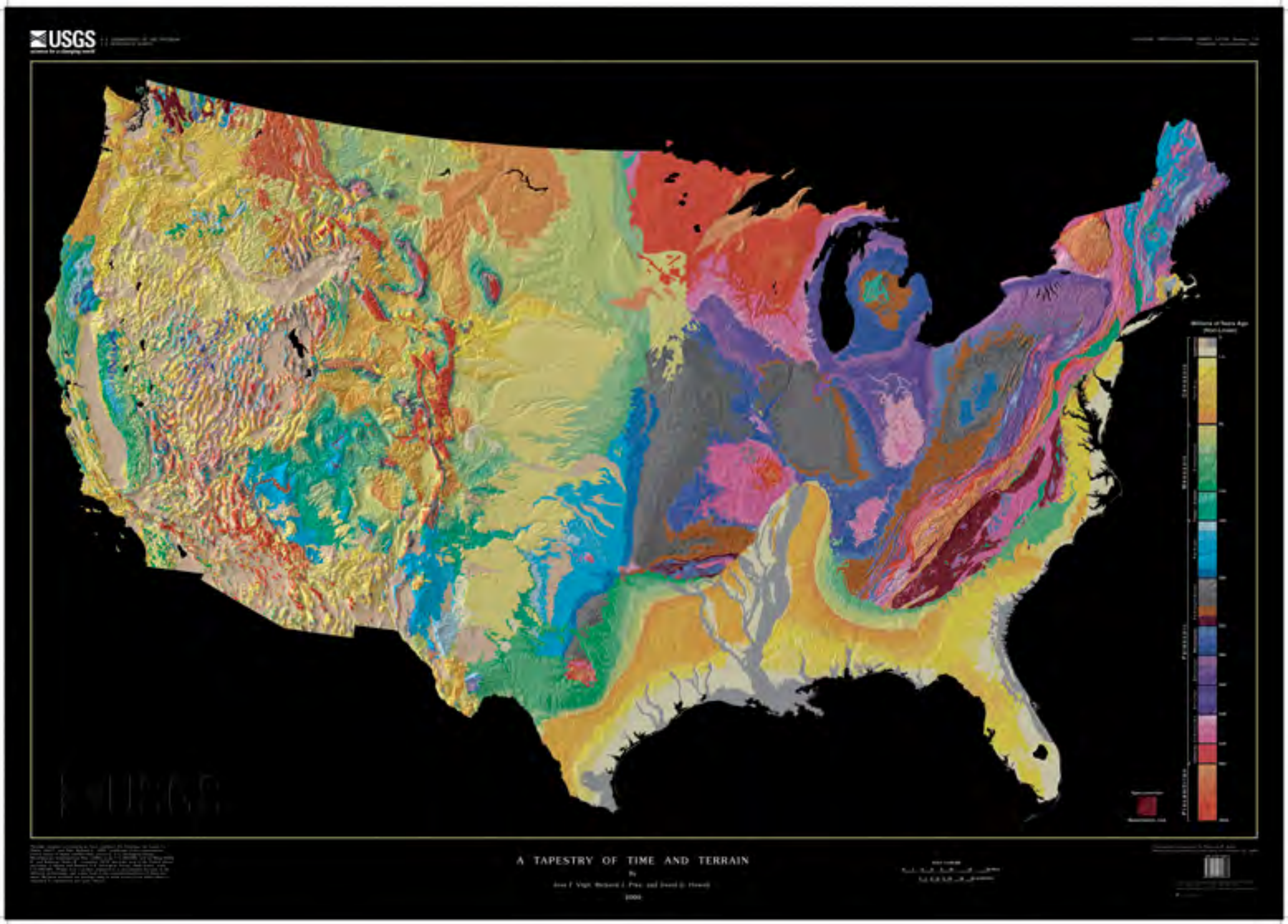


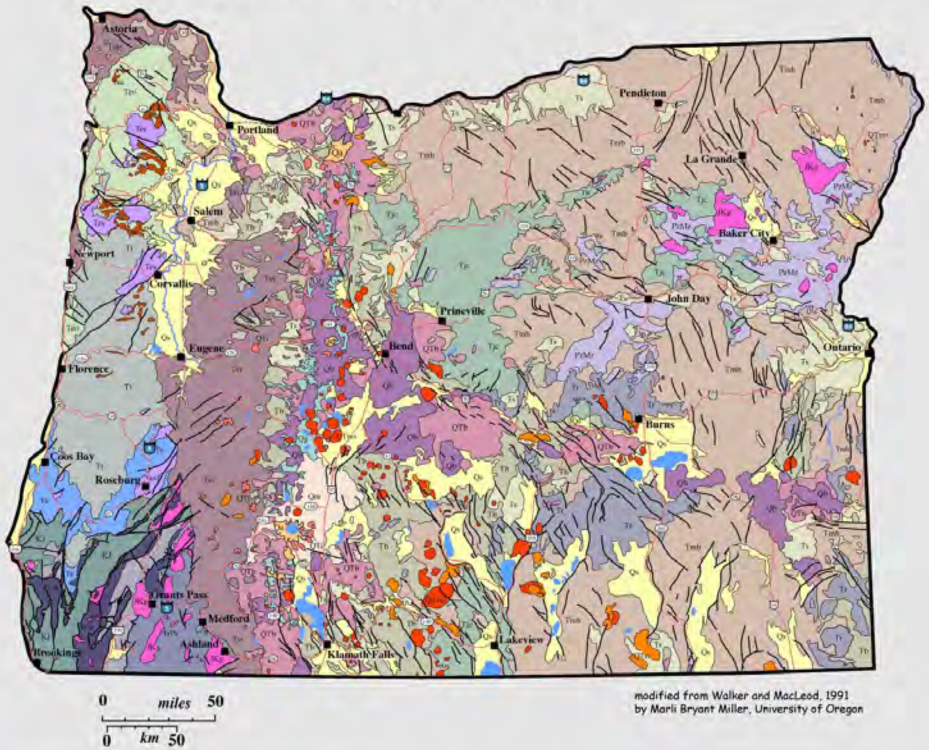


From Geological Road Map of Arizona (Arizona Geol. Survey/Arizona Geol. Society)

South Kaibab Fault


USGS
A TAPESTRY OF TIME AND TERRAIN

Geologic Map of Oregon



modified from Walker and MacLeod, 1991
by Marli Bryant Miller, University of Oregon

- **Qs** Quaternary sediment. Includes alluvium, colluvium, landslide, coastal dune, and terrace deposits.
- **Qm** Holocene Mazama ash and pumice. Includes air fall as well as flow deposits.
- **Qg** Quaternary Glacial Deposits.
- **Qa** Quaternary Andesite.
- **Qb** Quaternary Basalt and basaltic andesite. Forms some stratovolcanoes in the Cascades, and large basalt flows in eastern and central Oregon.
- **QTb** Quaternary, Pliocene, and some upper Miocene basalt flows.
- **Ts** Miocene, Pliocene, and some Quaternary sedimentary rocks, dominantly tuffaceous and contains tuff and volcanic breccia. Locally grades into Tb.
- **QTsv** Quaternary and Late Tertiary silicic vent complexes.
- **QTmv** Quaternary and Late Tertiary mafic vent complexes.
- **Tb** Middle to Upper Miocene and some Pliocene basalt.
- **Tmb** Middle Miocene basalt. Predominantly the Columbia River Basalt Group, including the Saddle Mtn., Wanapum, Grande Ronde, Picture Gorge, Imnaha basalt, as well as the basalt of Steens Mtn and other undifferentiated early-Miocene basalts. Also includes minor intervening tuffaceous sedimentary rocks, lakebed deposits, and silicic flows.
- **Tms** Lower to Middle Miocene marine sedimentary rock of the Coast Range.
- **Tsv** Eocene through Lower Miocene sedimentary and volcanic rock of the western Cascades. Includes the marine Eugene Fm., and the non-marine Fisher Fm of the southern Willamette Valley.
- **Tr** Eocene to Miocene rhyolite and rhyolitic tuff.
- **Tjc** Eocene to Lower Miocene sedimentary and volcanic rocks of the Clarno and John Day Formations, and related rocks.
- **Teo** Eocene to Oligocene marine volcanic-rich sedimentary and volcanic rocks. Includes Yamhill, Cowlitz, and Alsea Formations plus Yachats Basalt and Tillamook Volcanics.
- **Tt** Eocene Tyee Formation of the Coast Range.
- **Te** Eocene marine sandstone and siltstone that pre-dates Tyee Formation.

Rock of Accreted Terranes

- **Tes** Paleocene to Eocene basaltic and related rocks of the Siletz River Volcanics ("Siletzia").
- **KJ** Jurassic and Cretaceous sedimentary rock of the Franciscan Complex, found in the Klamath Mtns.
- **Jop** Jurassic volcanic, ultramafic, and metamorphic rock of the Klamath Mtns.
- **TrPz** Paleozoic and Triassic rock of the Klamath Mtns.
- **PzMz** Paleozoic and Mesozoic rock of eastern Oregon.

Intrusive Rock

- **QTi** Quaternary and Tertiary silicic and mafic intrusions of the Cascades.
- **Tmi** Tertiary, mostly Miocene mafic intrusions of Coast Range.
- **JKg** Jurassic and Cretaceous granitic intrusions of the Klamath and Blue Mtns.

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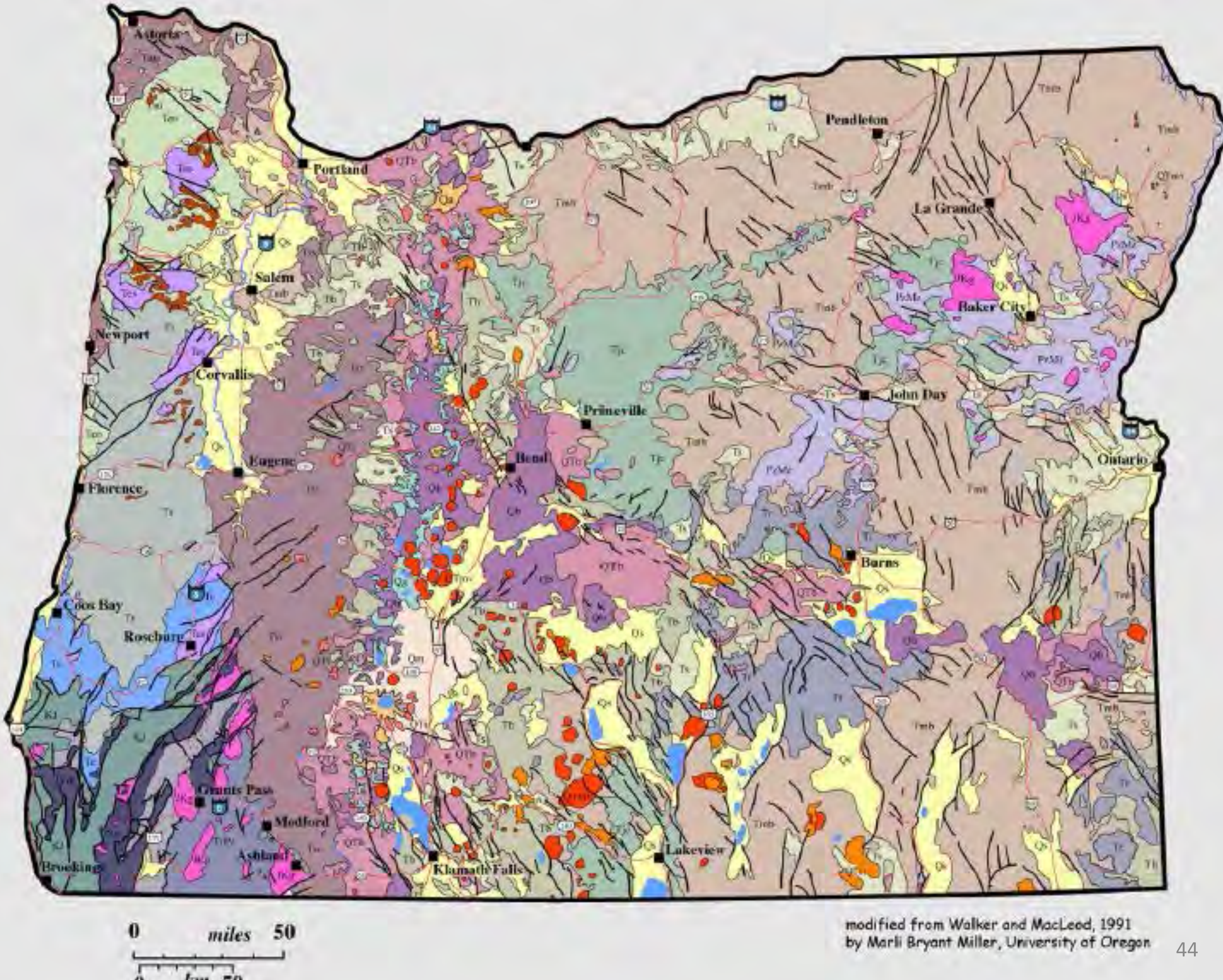

modified from Walker and MacLeod, 1991
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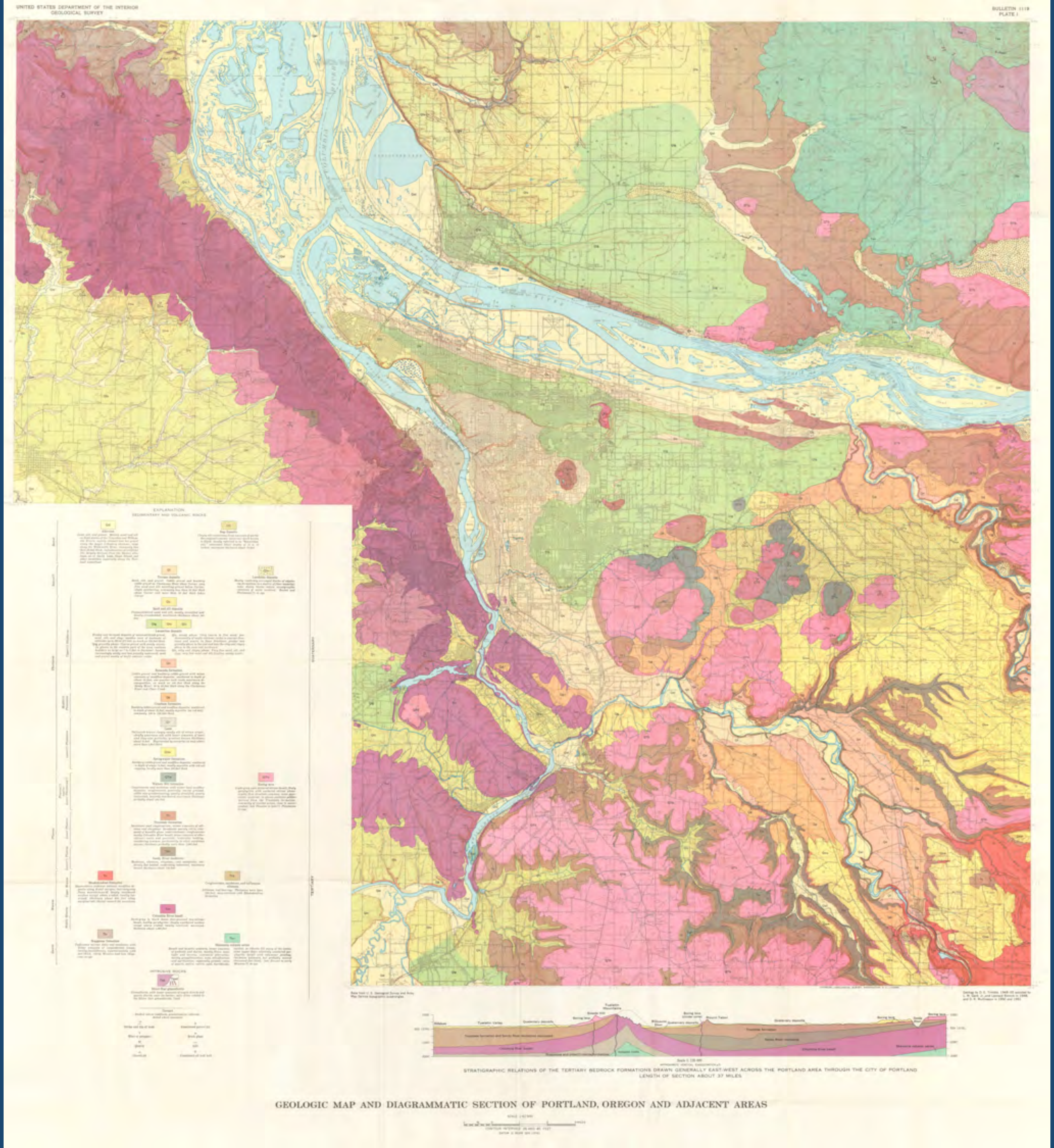
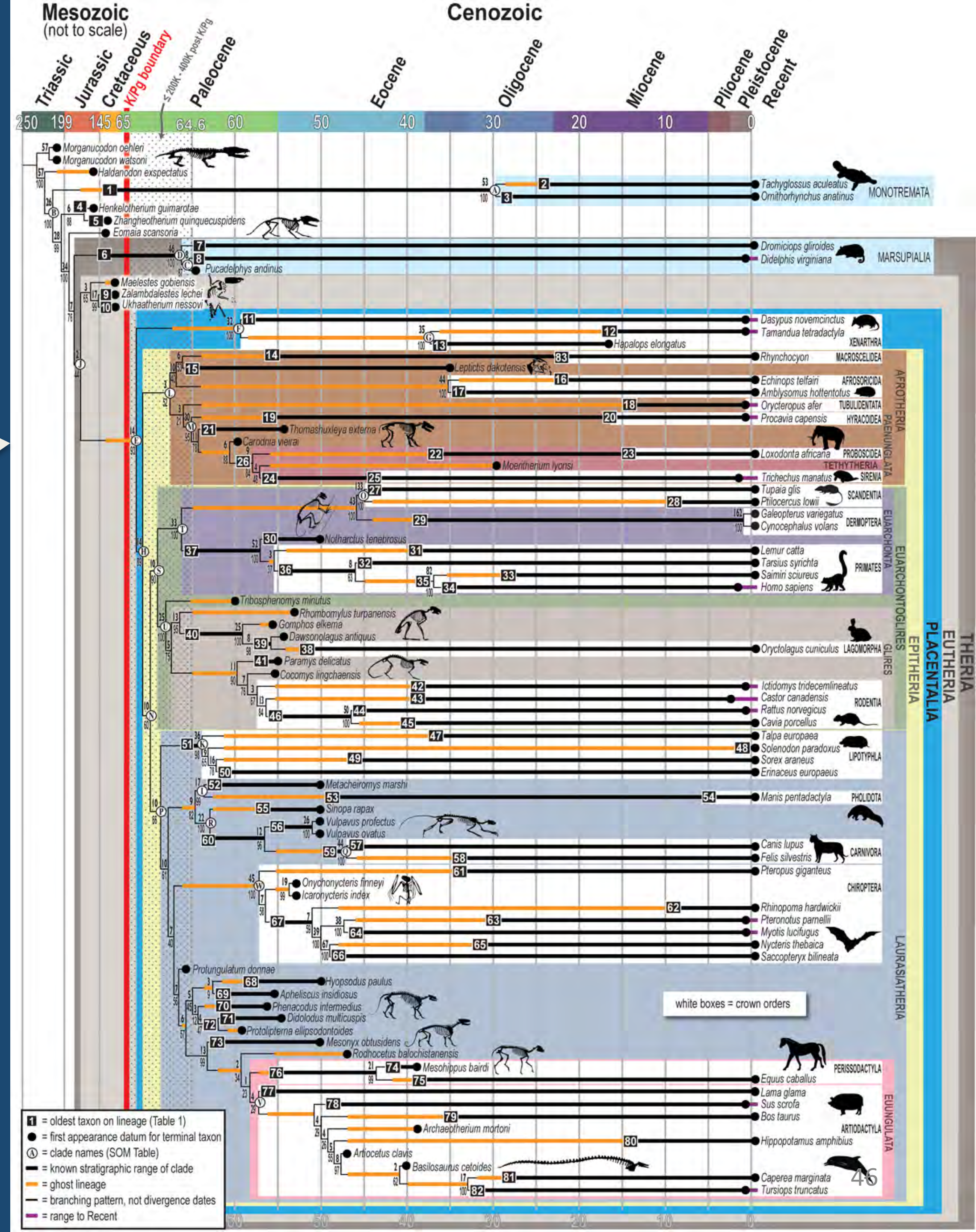
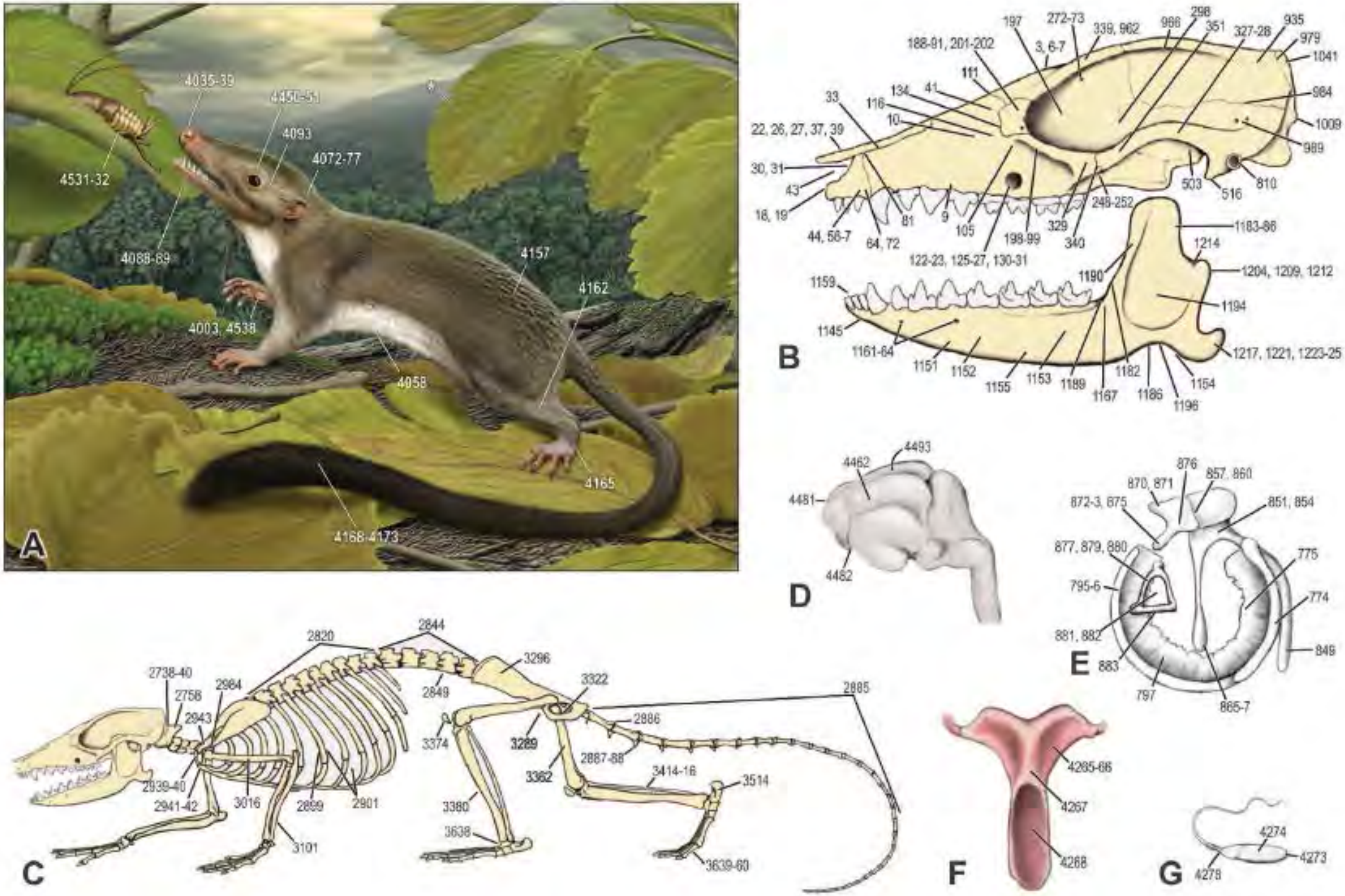

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
BULLETIN 1119
PLATE 1
EXPLANATION
STRATIGRAPHIC RELATIONS OF THE TERTIARY BEDROCK FORMATIONS DRAWN GENERALLY EAST-WEST ACROSS THE PORTLAND AREA THROUGH THE CITY OF PORTLAND
LENGTH OF SECTION ABOUT 37 MILES
GEOLOGIC MAP AND DIAGRAMMATIC SECTION OF PORTLAND, OREGON AND ADJACENT AREAS



O"leary et al 2013



O’Leary et al 2013