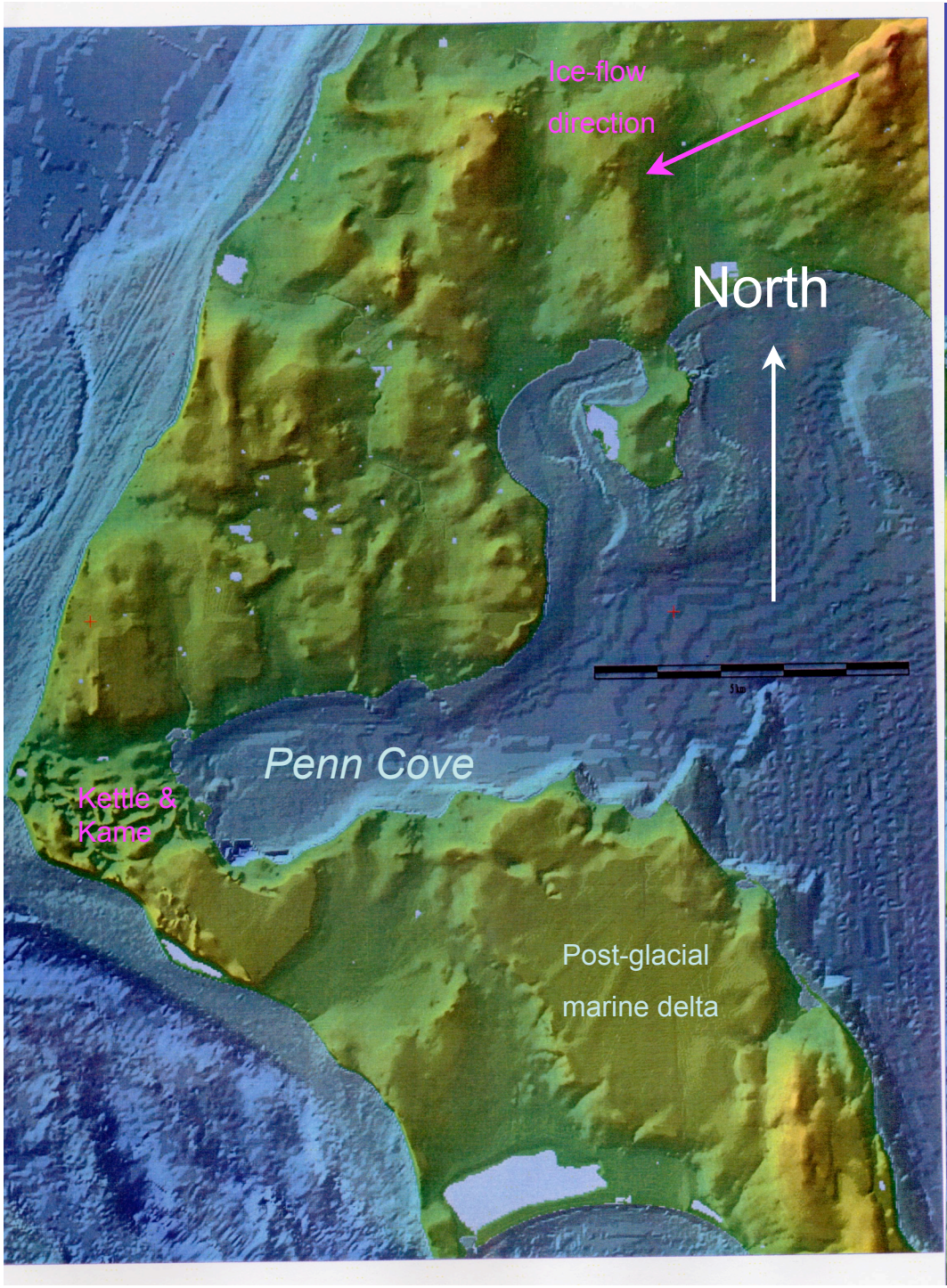
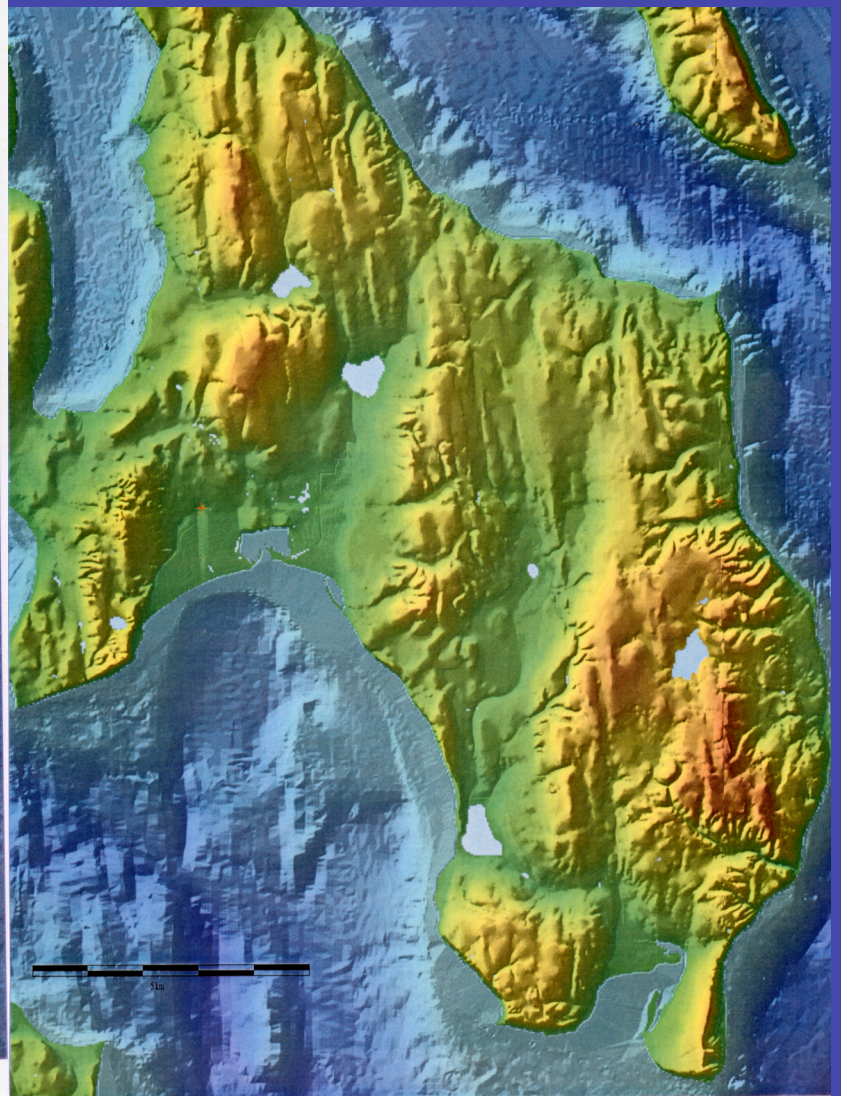
Glaciated terrains represent some of the most beautiful landscapes in the world. Yosemite National Park, California is a classic alpine glaciated landscape.

Many of the high Cascade mountains, inlcuding Mt. Rainier, retain modern glaciers. As recent as 15,000 years ago, during the last glacial cycle, Cascade glaciers were more extensive and terminated at elevations several 1000 feet lower than today. Geomorphic evidence is well-preserved within the present U-shaped valleys occupied by modern streams.

Glaciers also left their signature over much of the Puget Lowland 15,000 years ago. Both erosional and depostional landforms from the most recent glaciation dominate the surface landscape. This imprint from the Puget Lobe glacier is easily seen on the small-scale DEM image shown on the left.

Glacial features such as kettle and kames, glacial marine deltas and ice-streamlined topography are seen on the 10 m DEM image of central and south Whidbey Island.





Much of the sediment record exposed in unconsolidated bluffs lying adjacent to the Puget Sound are glacial in origin. Non-glacial sediment units, mainly alluvium are present in the lower exposed sections. This image was taken from the Double Bluff, Whidbey Island.

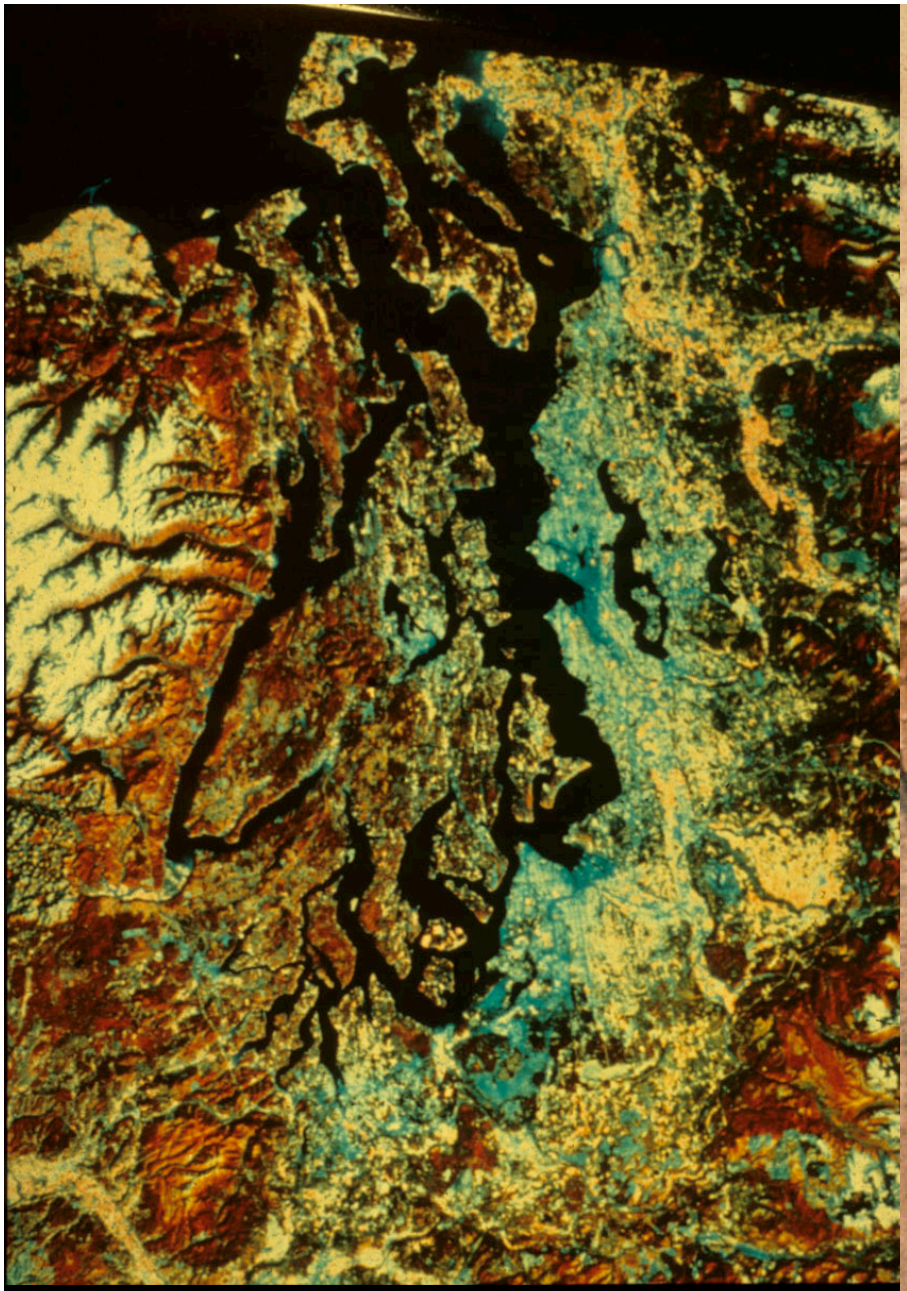
We can use modern glaciated analogs to recognize that cirques, U-shaped valleys, and other glacial features are the result of glacial erosion and deposition. This inference was more difficult to make in locations previously occupied by continental-scale ice sheets, where we have no comparative analog.

Fjord landscapes, such as along the coast of Maine, represent drowned glaciated valleys that were occupied with rising marine waters following deglaciation.

The Alaskan tidewater glacier provides a nice analog to the glacial setting of the Puget Lowland during deglaciation ~15,000 years ago.

Vic Prest's (Canadian Geological Survey) reconstruction of the Cordilleran Ice Sheet has stood the test of time.

Even his age constraints on the timing of deglaciation has fared well with additional radiocarbon dating.



We now recognize that the Puget Lowland was occupied with glacial ice many times in the past and as recent as ~15,000 years ago.

Mt. Erie, Fidalgo Island is a classic stoss and lee landform. Ice flow was from your right to left (north to south) on the image.

Glacial grooves and striations are preserved on quartzite bedrock overrun by the Puget ice sheet.

Diverse lithology of glacial erratics and till boulders reflects the diverse bedrock lithology that was eroded and deposited by the Puget Lobe.

Coupeville erratic (Whidbey Island) was plucked from the lee side of Mt.Erie lying ~20 miles north of Coupeville.

Wedgewood erratic (near NE75th St. and 28th Ave) is one of the larger glacial erratics in the Seattle area. It is a greenstone and may have also been excavated from Fidalgo Island.

The Saratoga erratic (south Whidbey Island) is one of my favorites. It is over 30 feet tall and big enough to eat lunch on it. It was also excavated from Mt. Erie, Fidalgo Island.

The large Columbia basalt haystack erratics were excavated by the Okanogon Lobe from the Columbia Gorge and deposited north of Withrow, Washington.

The Vashon Till is well-exposed near the top section of many bluffs lying adjacent to the Puget Sound.

- **Glacial Theory**

- **The Glacial Theory:** the development of the idea that glaciers were formerly far more extensive than at present.

- **Important Players in the Development of Glacial Theory (*Ice Ages by* Imbrie and Imbrie (Ch. 1 and 2) provides a nice overview.**

- **1. Saussure (1786):** first to recognize erratics lying on the slopes of the Jura Mountains were derived from the Alps 80 km to the south.

- **2. William Buckland (1819):** Diluvial hypothesis reconciles geology and theology.

- **3. James Hutton (1788):** Principle of Uniformitarianism

- **4. Daniel Drake** (1817)**:** Iceberg Theory

- **5. Charles Lyell (1830):** *Principles of geology* -Continental Submergence
- "glacial drift"

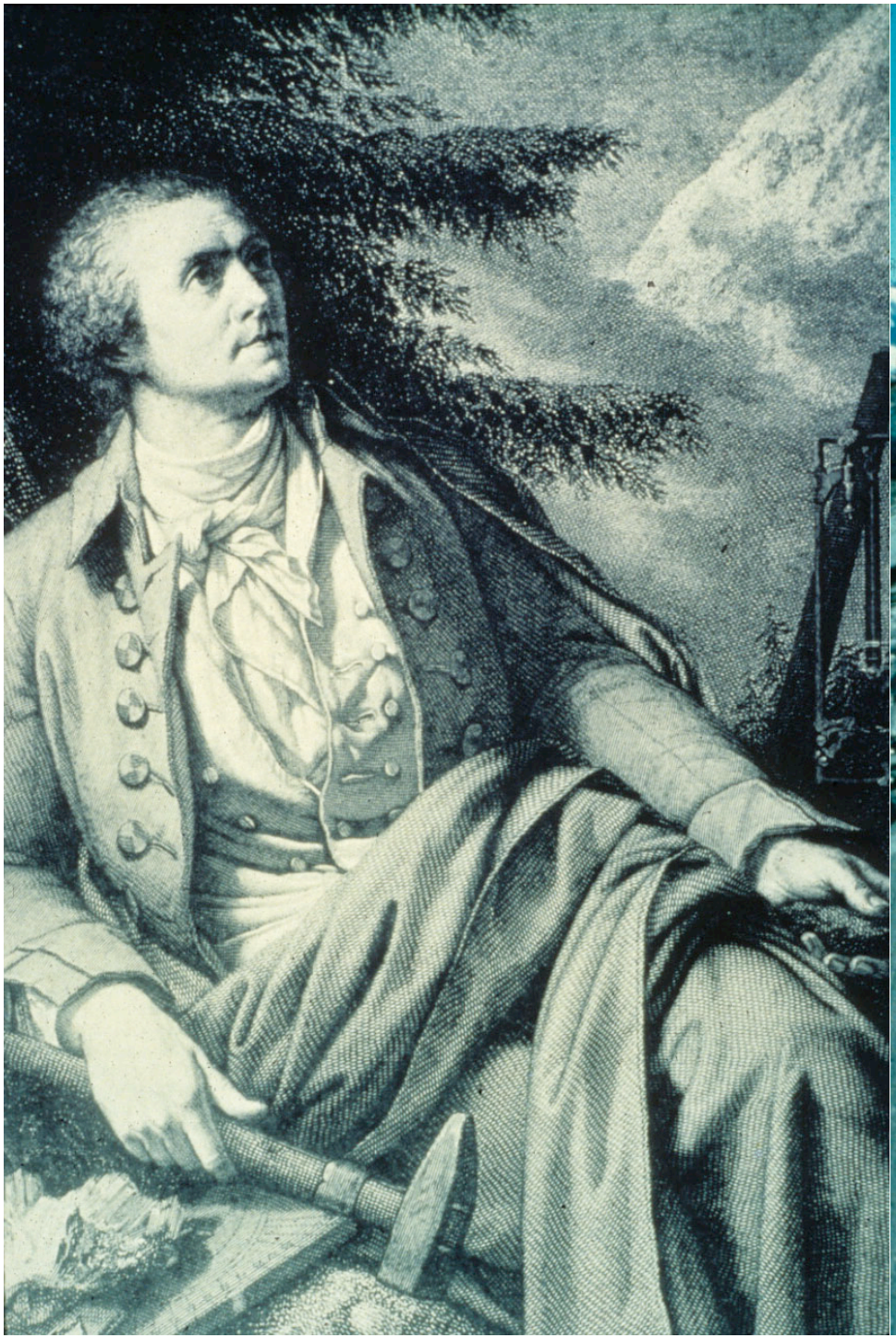
- **6. Ignace Venetz (1821;1829)**: reports to the Helvetic Society (Society of Natural History) that not only the Alps, but all of northern Europe had been extensively glaciated in the past. cites **Jean-Pierre Perraudin (1818).**

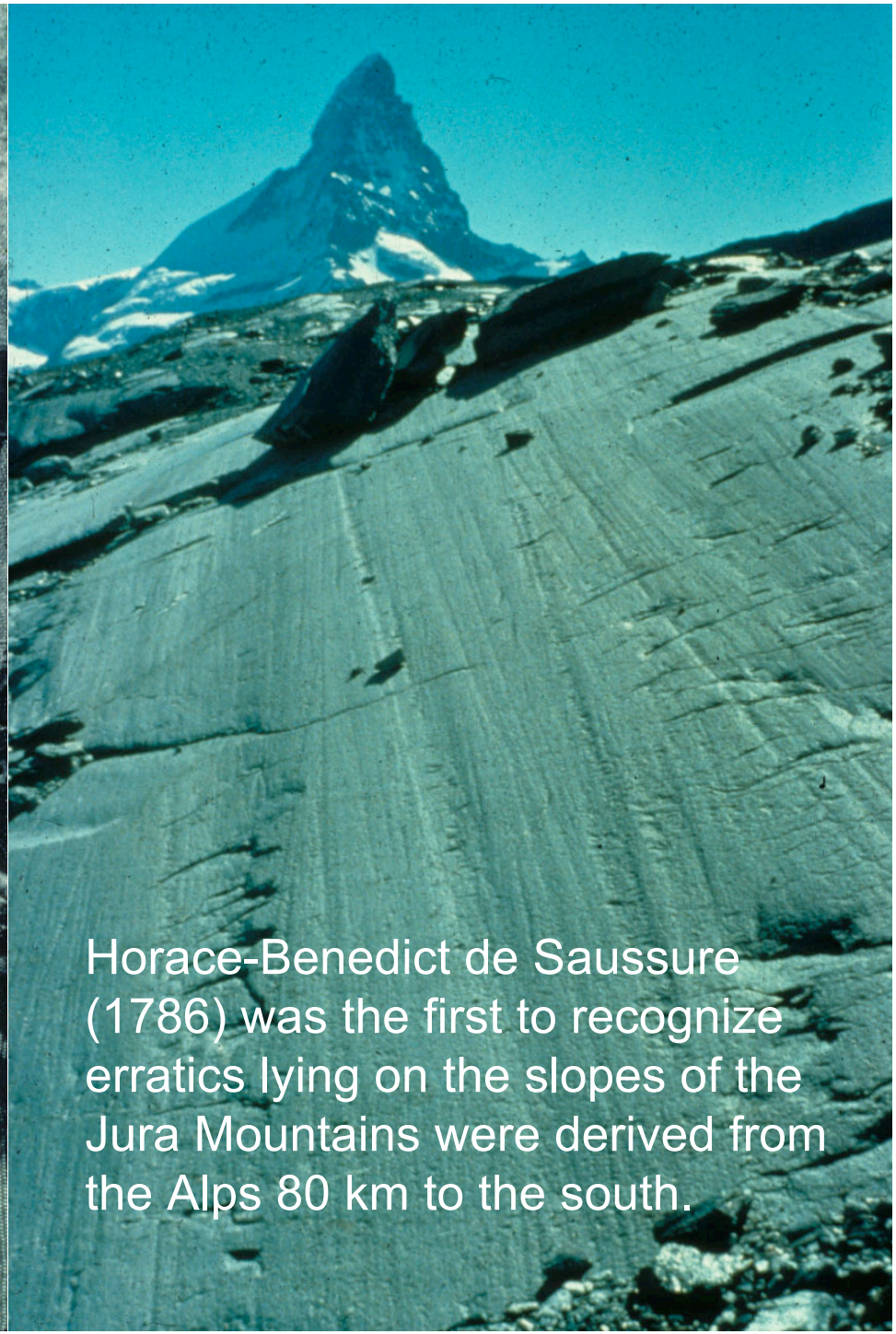
- **7. Jean de Charpentier (1834):** delivered a paper in Lucerne supporting Perraudin and Venetz.

- **8. A. Bernhardi (1832):** First to recognize that glacier ice from the North polar region had extended as far south as Germany. Bernhardi's ideas remained unnoticed to the scientific community.

- **9. Louis Aggasiz (1837):** Delivers the presidential address at the opening session of the Swiss Society of Natural Sciences. Concept of an "Ice Age" emerged.

- The glacial theory gained acceptance in Europe (Buckland and Lyell, 1839) and North America (Hitchcock, 1841).



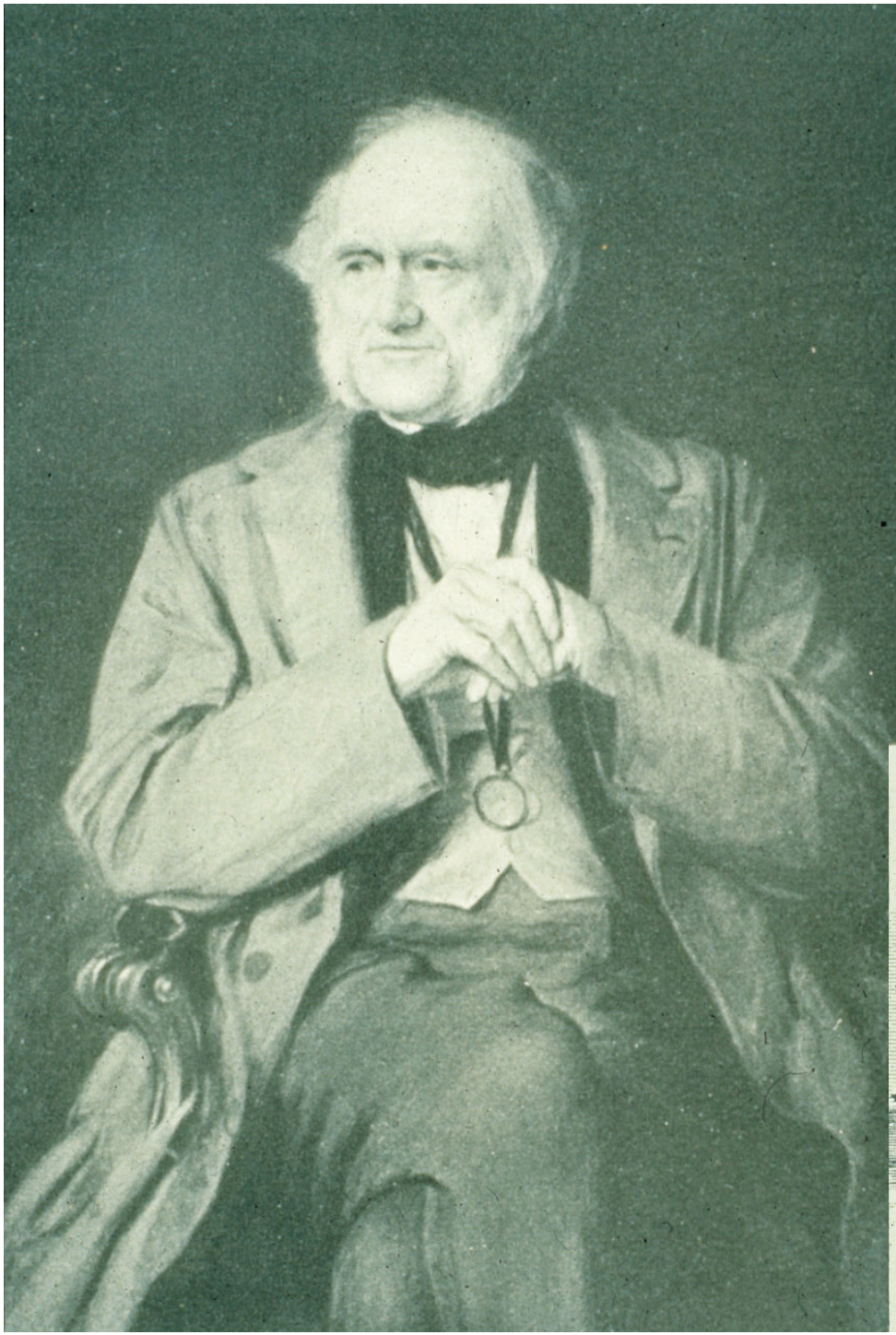


Horace-Benedict de Saussure (1786) was the first to recognize erratics lying on the slopes of the Jura Mountains were derived from the Alps 80 km to the south.

Dark granodiorite erratic boulder overlying light-colored dolomite bedrock in the White Mountains, CA.

Peat layers, which included plant macro-fossils, were described as “Noah’s Barnyard” and thought to contain remains from the Noahian flood.

Strand lines such as these surrounding Hudson Bay would have been interpreted as being formed as floodwaters subsided instead of being caused by isostatic rebound and recent emergence of the shoreline.



Charles Lyell published *Principles of Geology* in 1830.

To explain the presence of glacial erratics found at high elevations, he proposed the idea of broad continental submergence and ice-rafting by berg ice.

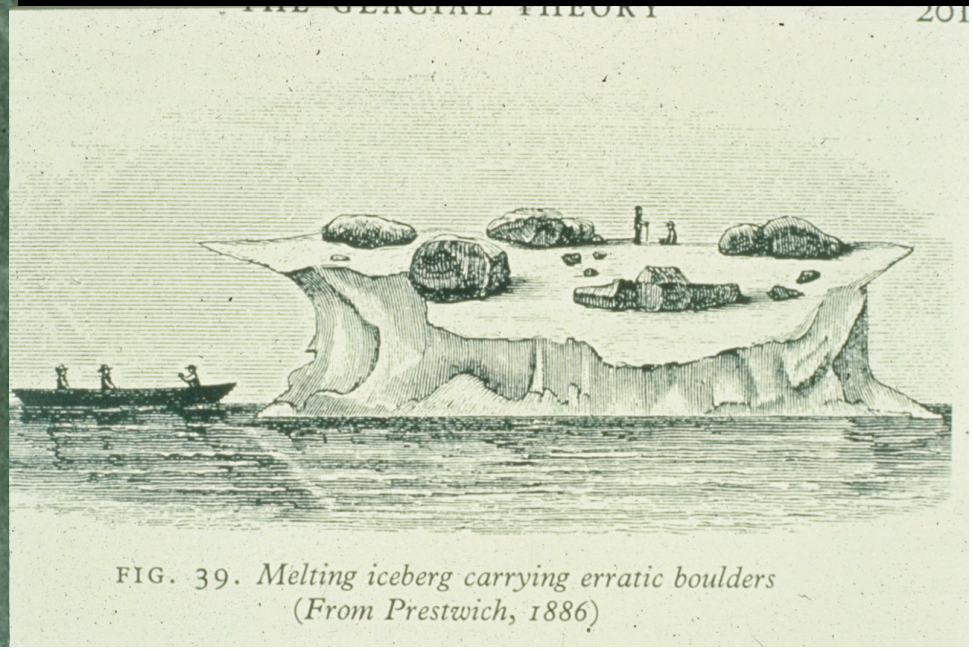
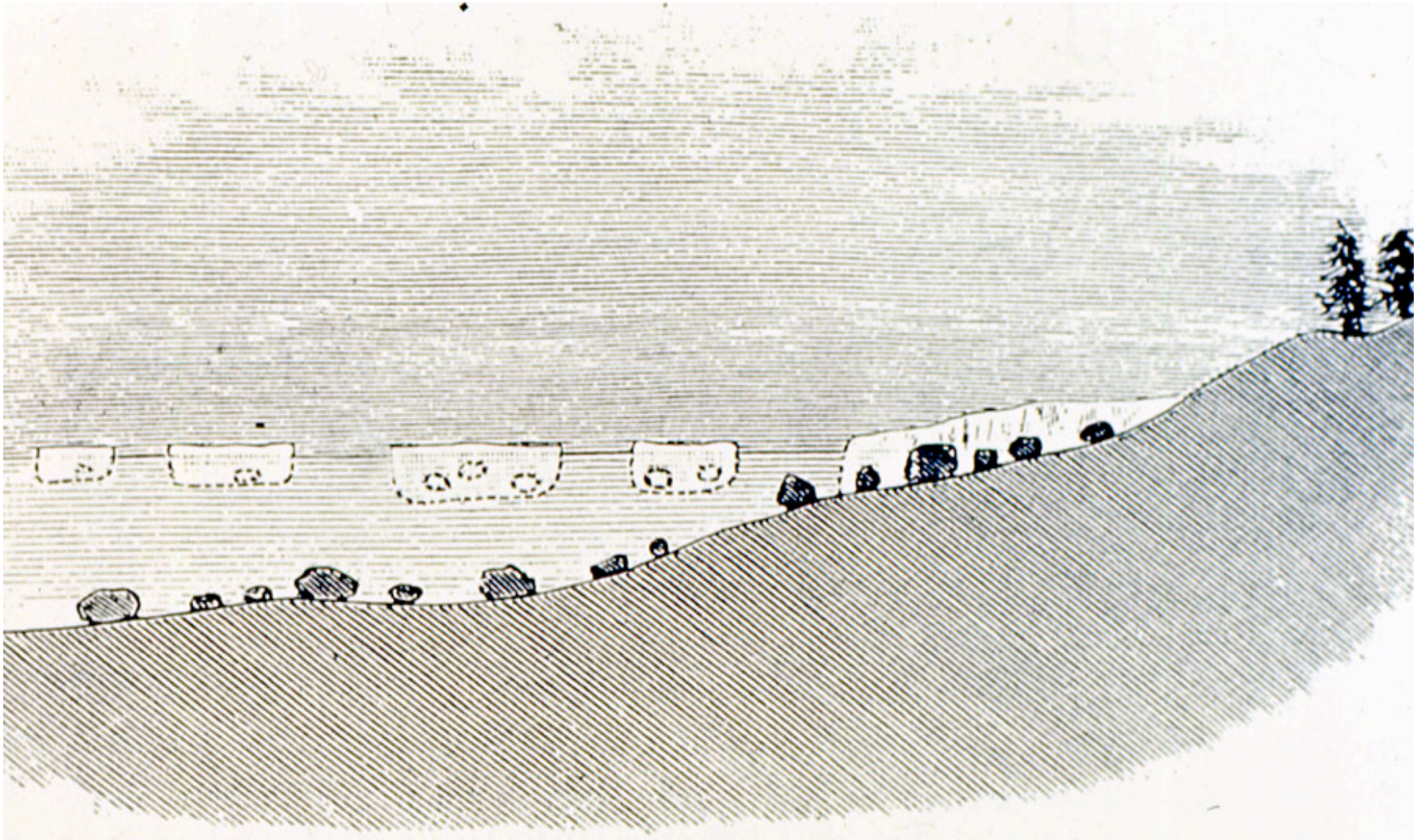


FIG. 39. *Melting iceberg carrying erratic boulders (From Prestwich, 1886)*

How would you explain the presence of this large Whidbey Island erratic lying 250 feet above sea level without a context of “glacial theory?”

By the 19th century polar exploration had exposed scientists to the idea of ice-rafting as a mechanism to transport sediment.



o. *The nineteenth-century concept of the drifting of erratics by icebergs (From Prestwich, 1886)*

Erratics in the Ohio Valley and other locations around the world could be explained general submergence and ice-rafting, advocated by Daniel Drake (1817).

Ignace Venetz reports to the Helvetic Society (1829) that glaciers had spread out over much of northern Europe well beyond the Alps.

ESSAI

SUR

LES GLACIERS

ET SUR

LE TERRAIN ERRATIQUE DU BASSIN DU RHONE,

par

JEAN DE CHARPENTIER,

DIRECTEUR DES MINES DU CANTON DE VAUD,

ET PROFESSEUR HONORAIRE DE GÉOLOGIE A L'ACADÉMIE DE LAUSANNE;

Membre de la Société helvétique des sciences naturelles; des Sociétés des sciences de Lausanne, de Marbourg, de Dresde, de Hanau, de Breslau et de Leipsick; membre étranger de la Société géologique de Londres; correspondant de l'académie royale des sciences, inscriptions et belles-lettres de Toulouse, et des Sociétés philomatique, linéenne, et d'histoire naturelle de Paris, de Strasbourg, etc.

Avec des vignettes, des planches, et une carte du terrain erratique du bassin du Rhône.

LAUSANNE,
IMPRIMERIE ET LIBRAIRIE DE MARC DUCLOUX, ÉDITEUR.

1841.

Jean de Charpentier spent five years (1829-1833) organizing and classifying evidence in support of glacial theory. He faced considerable resistance from the scientific community.

Reinhard Bernhardi first to recognize that ice from the polar regions extended as far south as the northern German plain. Ideas never became know in the scientific community.

Louis Aggasiz (1837) delivered his presidential address at opening session of the Swiss Society of Natural Sciences after spending several years in the field with de Charpentier.

Louis Agassiz in 1844

STUDIES ON GLACIERS

preceded by the

DISCOURSE OF NEUCHÂTEL

by

Louis Agassiz

translated and edited by

ALBERT V. CAROZZI

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HP