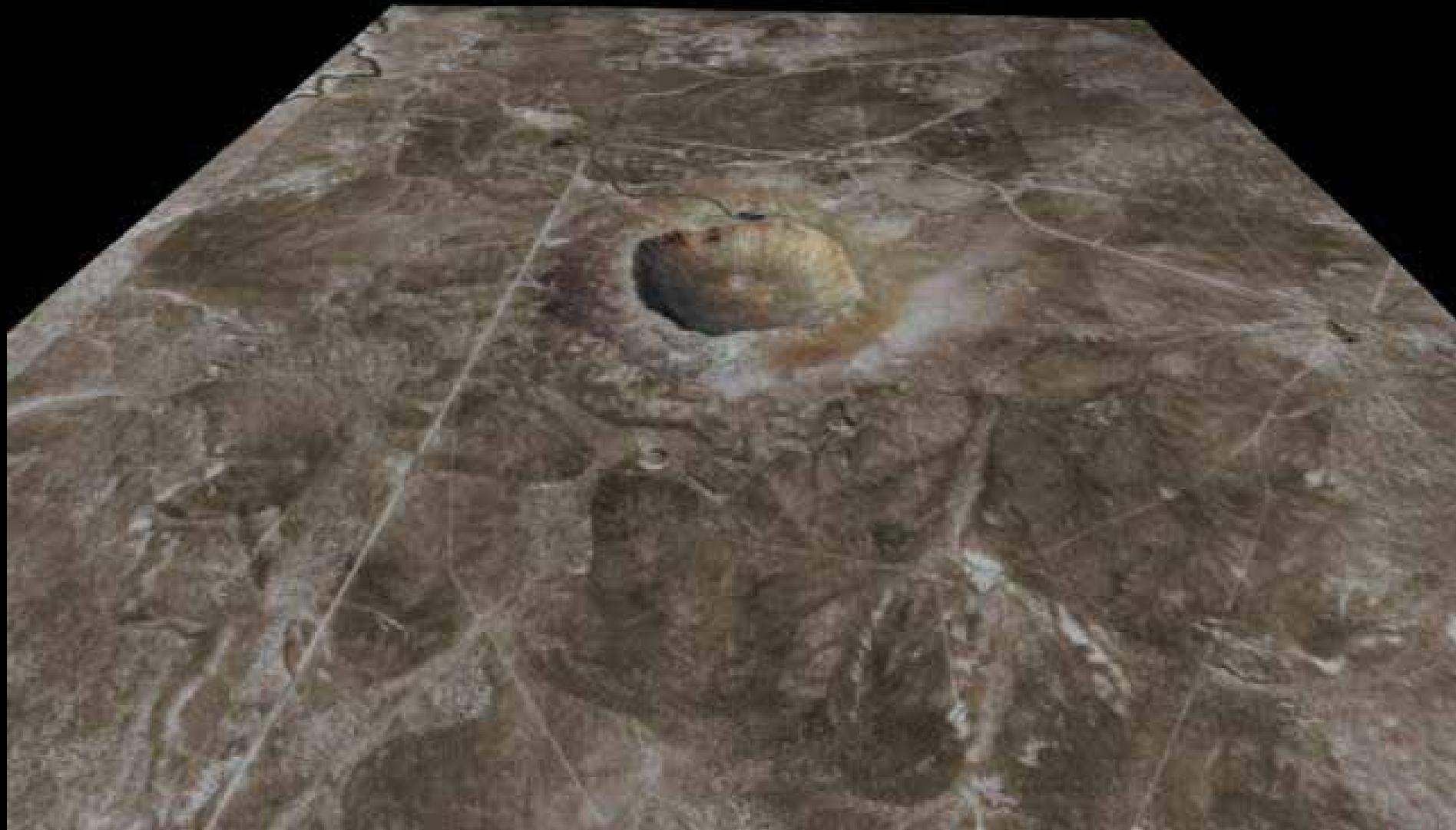


The NEA Impact that Created Meteor Crater, Arizona

David A. Kring

USRA - Lunar and Planetary Institute
Houston, TX

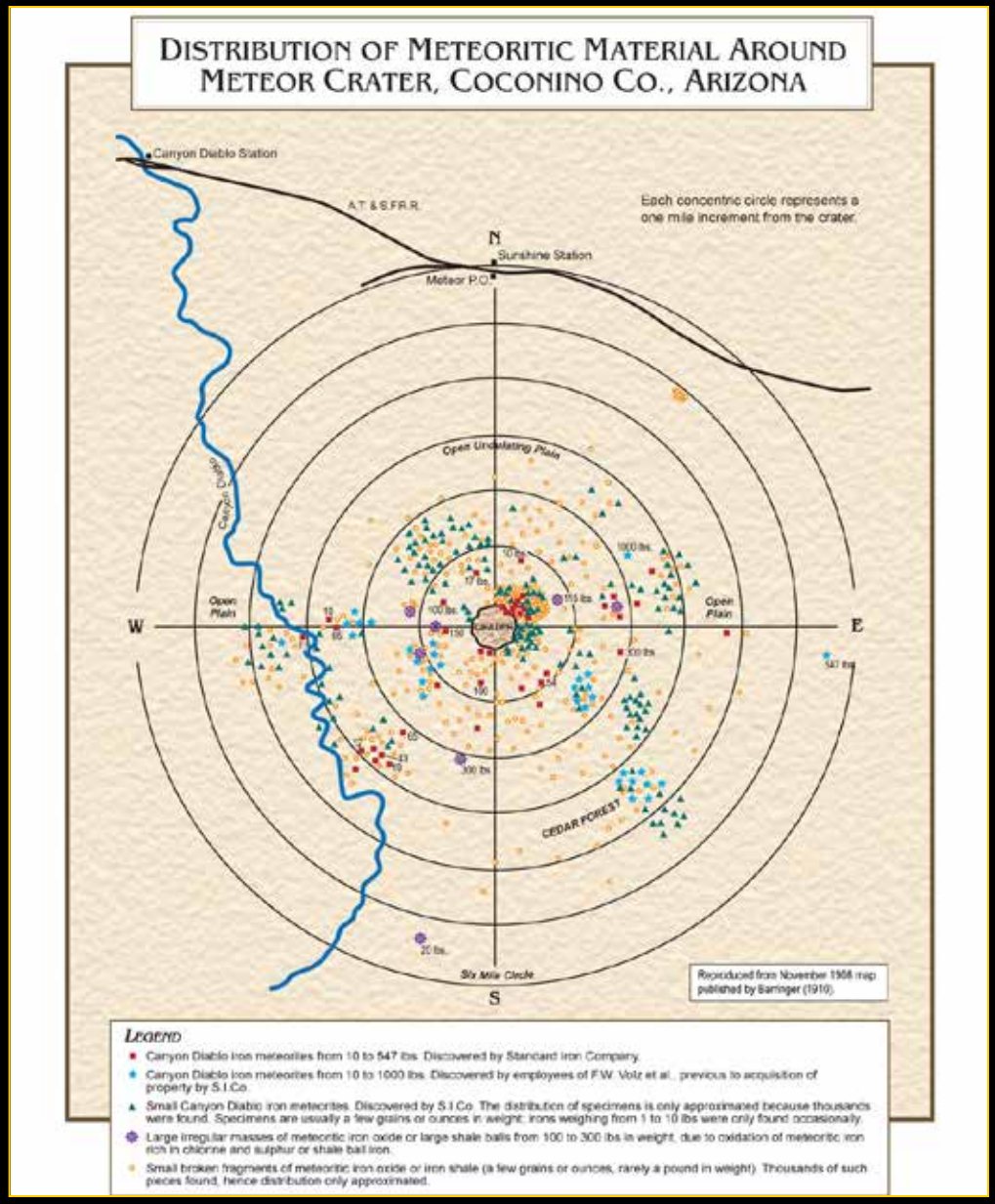
First Proven Impact Crater

Daniel M. Barringer

- Iron meteorites at crater
- Meteorite abundances increase towards crater
- Iron meteorites are within the ejecta blanket and crater breccia lens

Canyon Diablo Meteorite

Barringer (1903, 1905, 1910)



Evidence of an Impact Origin

Shock Metamorphism

- Pulverized target sandstone
- Quartz with planar deformation features
- Stishovite & coesite
- Impact melts
  - splashes & coatings
  - melt spherules (i.e., with aerodynamic forms)
  - irregular melt particles that are vesicular; produced when sandstone & dolomite were melted, mixed, and carbon dioxide was degassed.

Work by Barringer, Nininger, Shoemaker, Kieffer, Chao

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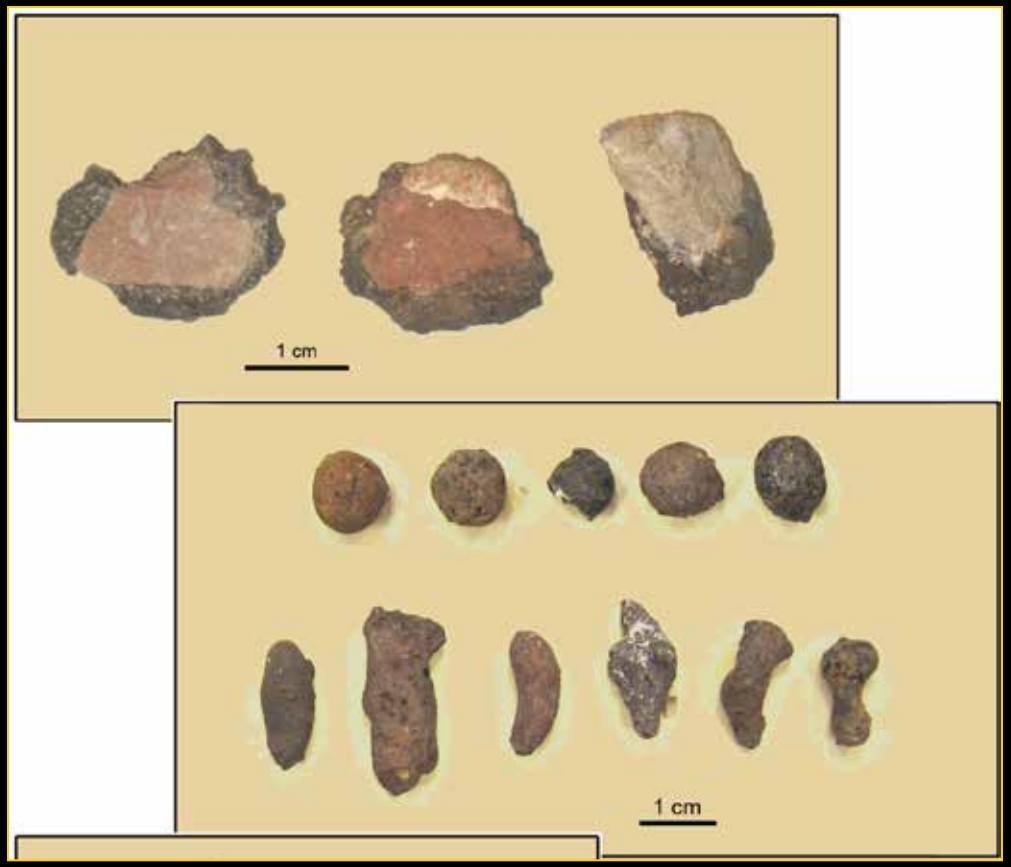
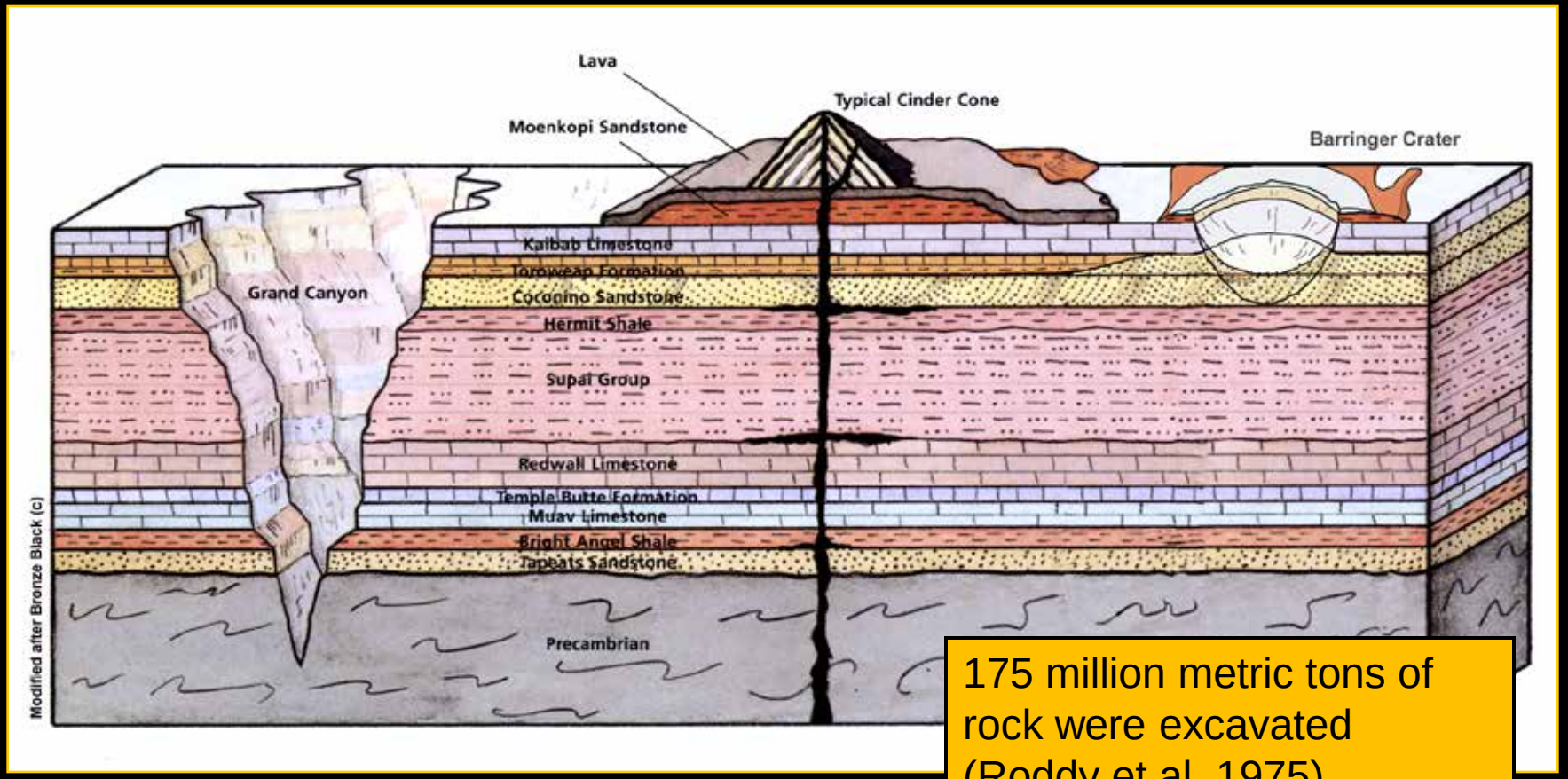


Melts do not lie on magmatic liquid lines of descent

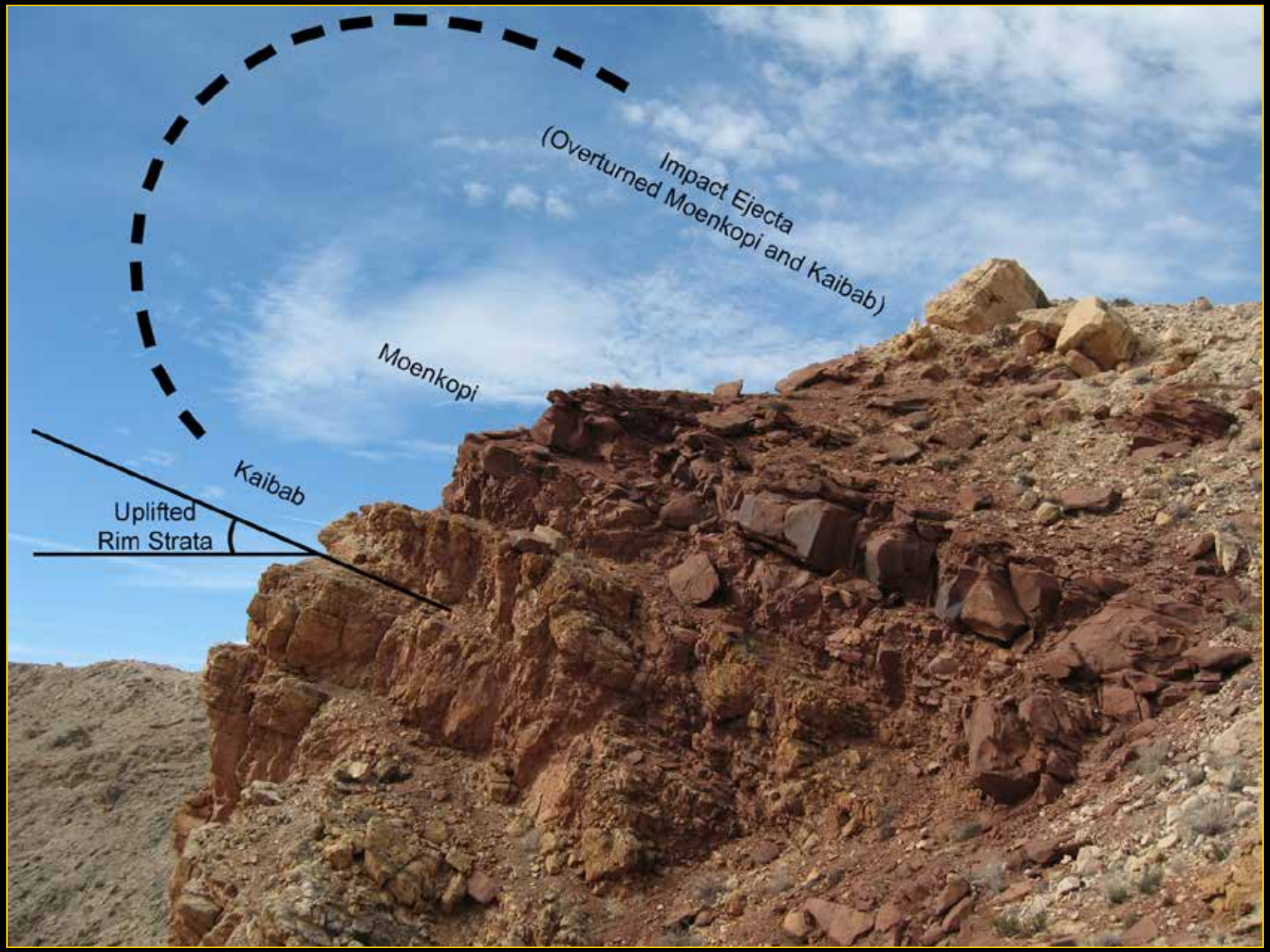
Work by Barringer, Nininger, Shoemaker, Kieffer, Chao

Excavation of Upper Grand Canyon Sequence



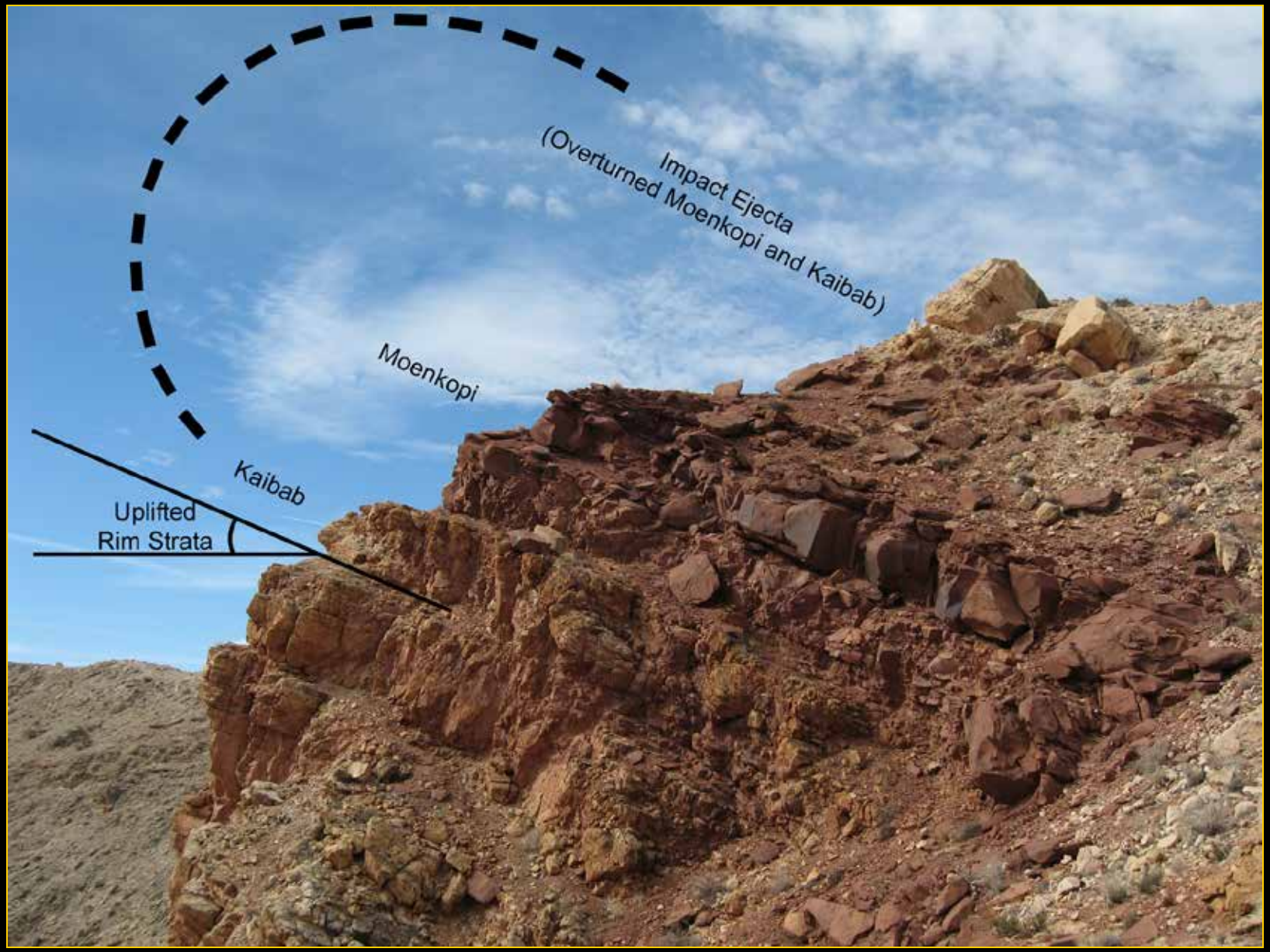
175 million metric tons of rock were excavated (Roddy et al. 1975)

Uplifted Crater Walls in Upper Grand Canyon Sequence



Uplifted Crater Walls

Uplifted Crater Walls & Overturned Strata

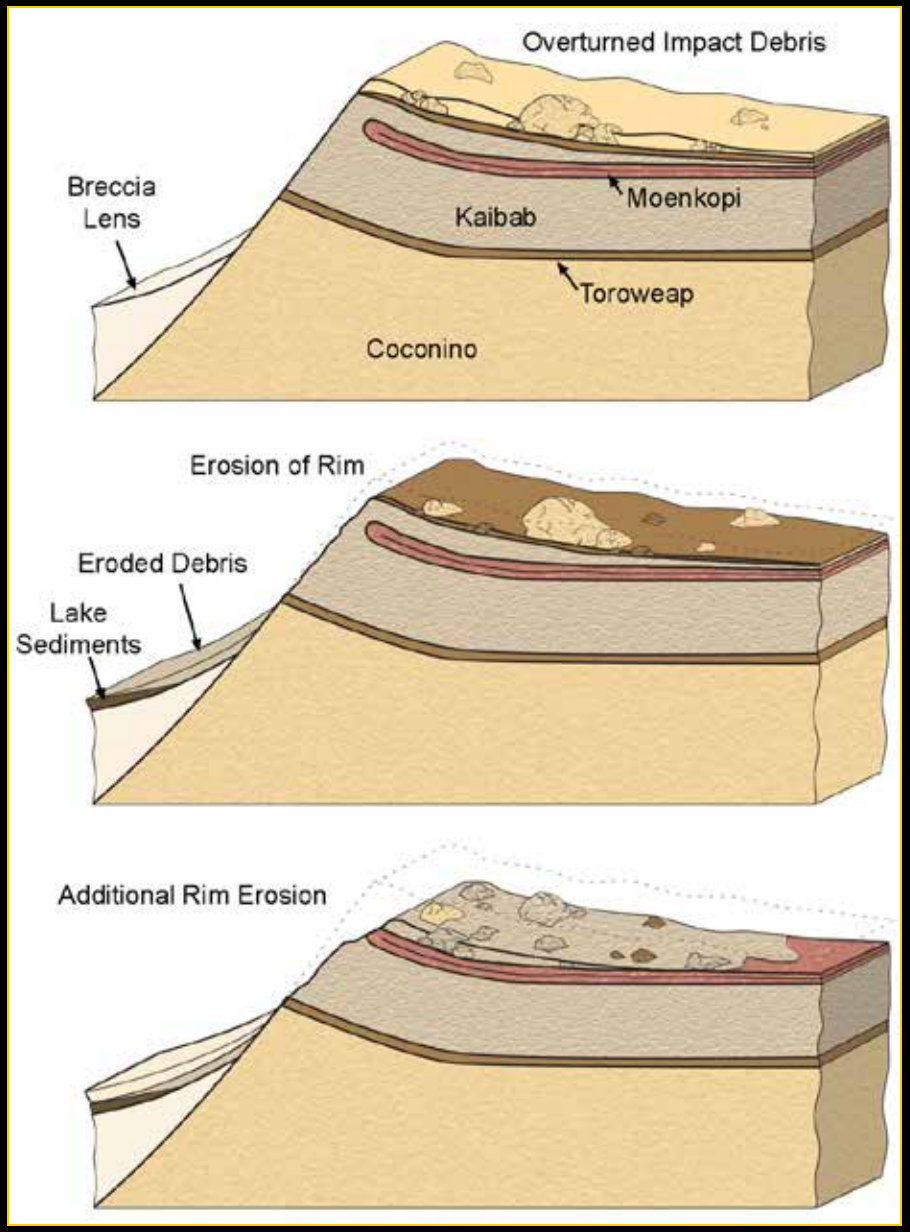


Structural & Stratigraphic Overturning in Crater Rim

Formation of Crater Rim
(& overturned sequence)

Subsequent erosion
reduces rim height

&
Exposes fold hinges



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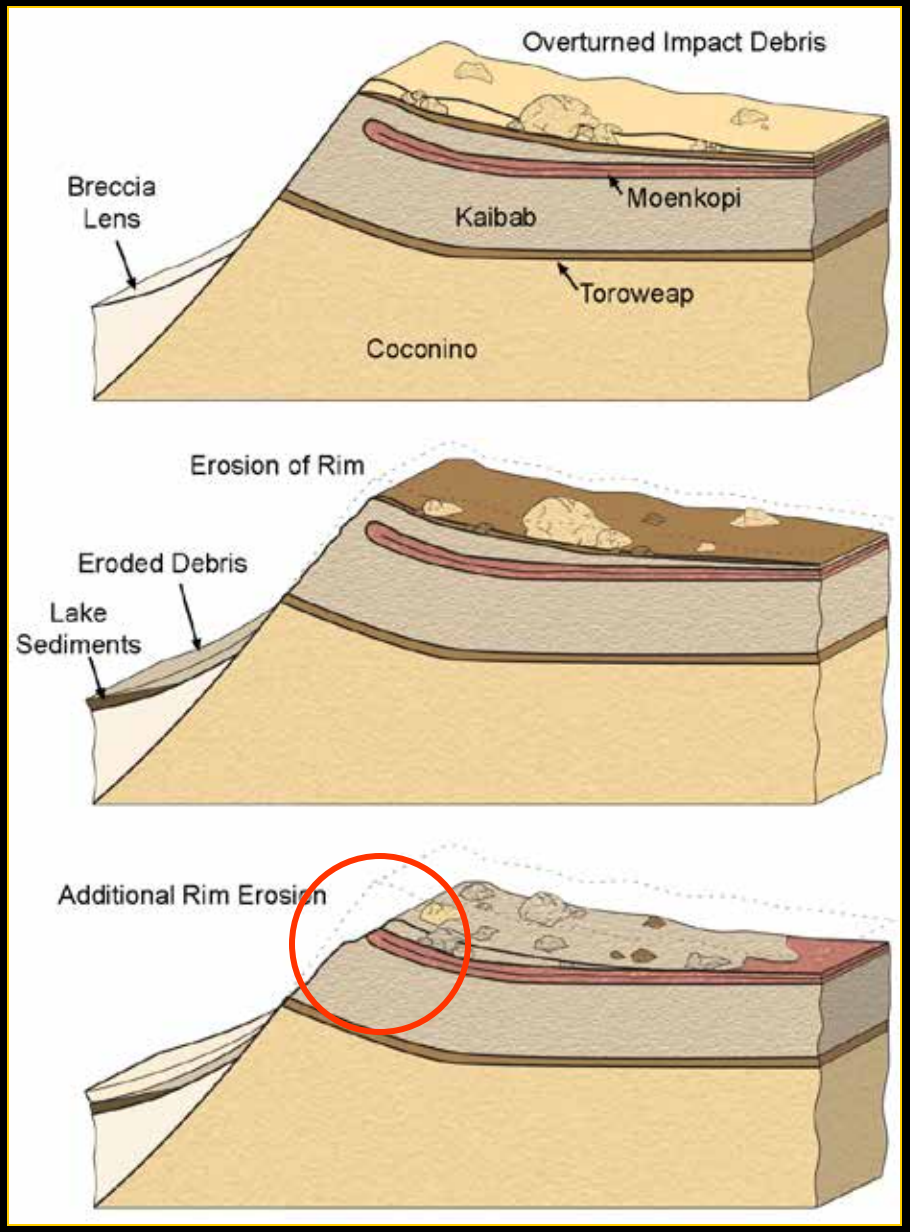
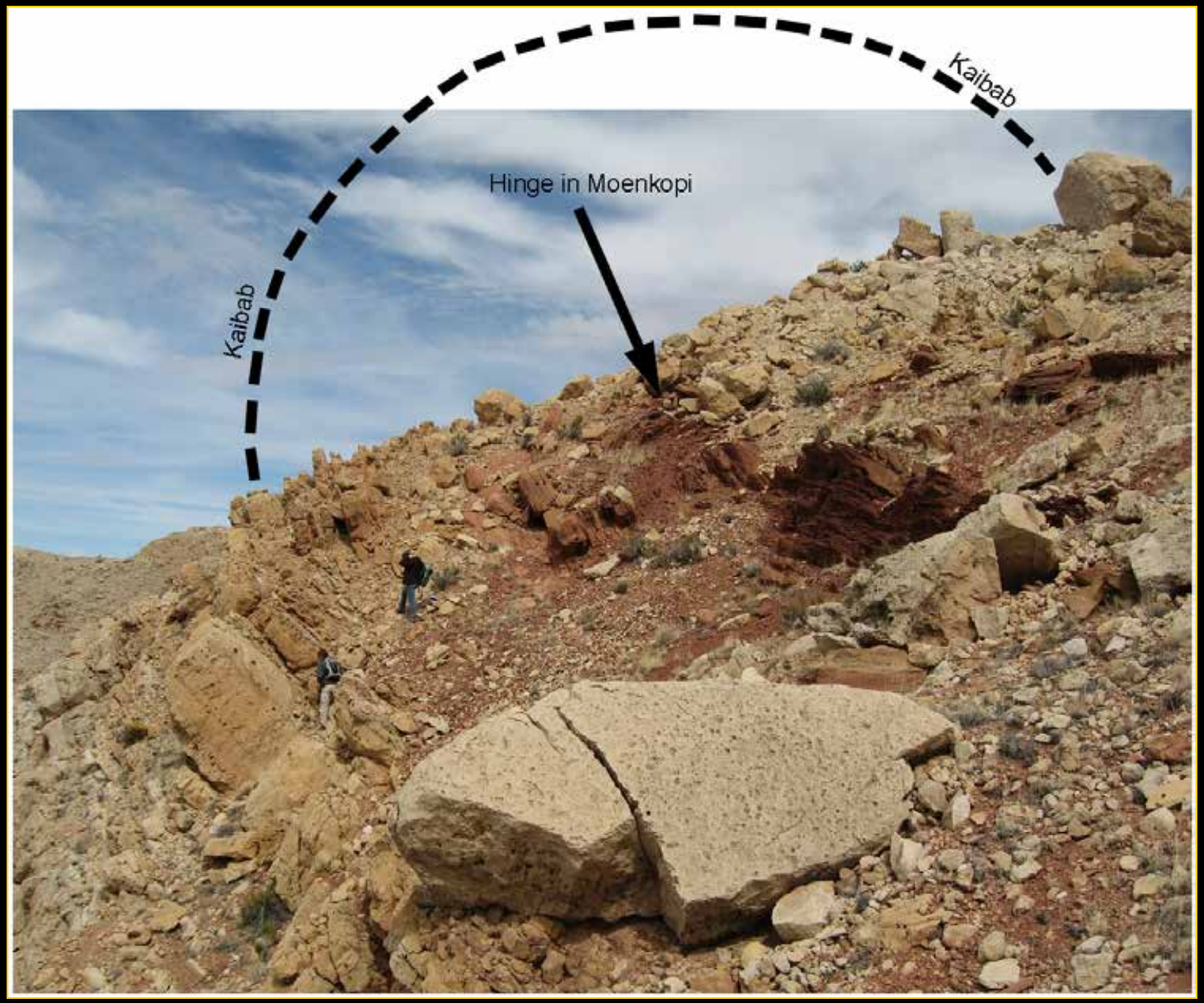
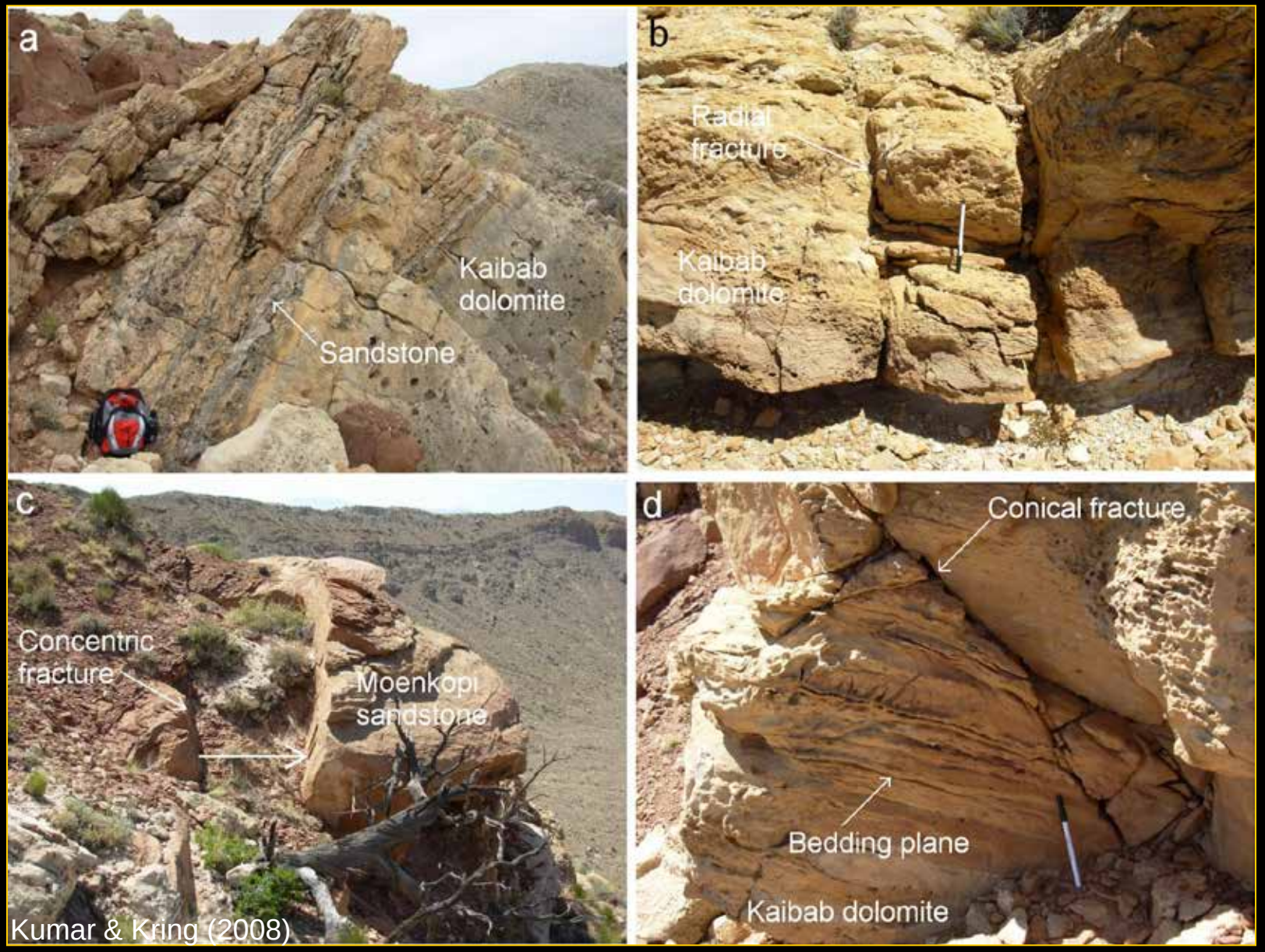


Structural & Stratigraphic Overturning in Crater Rim



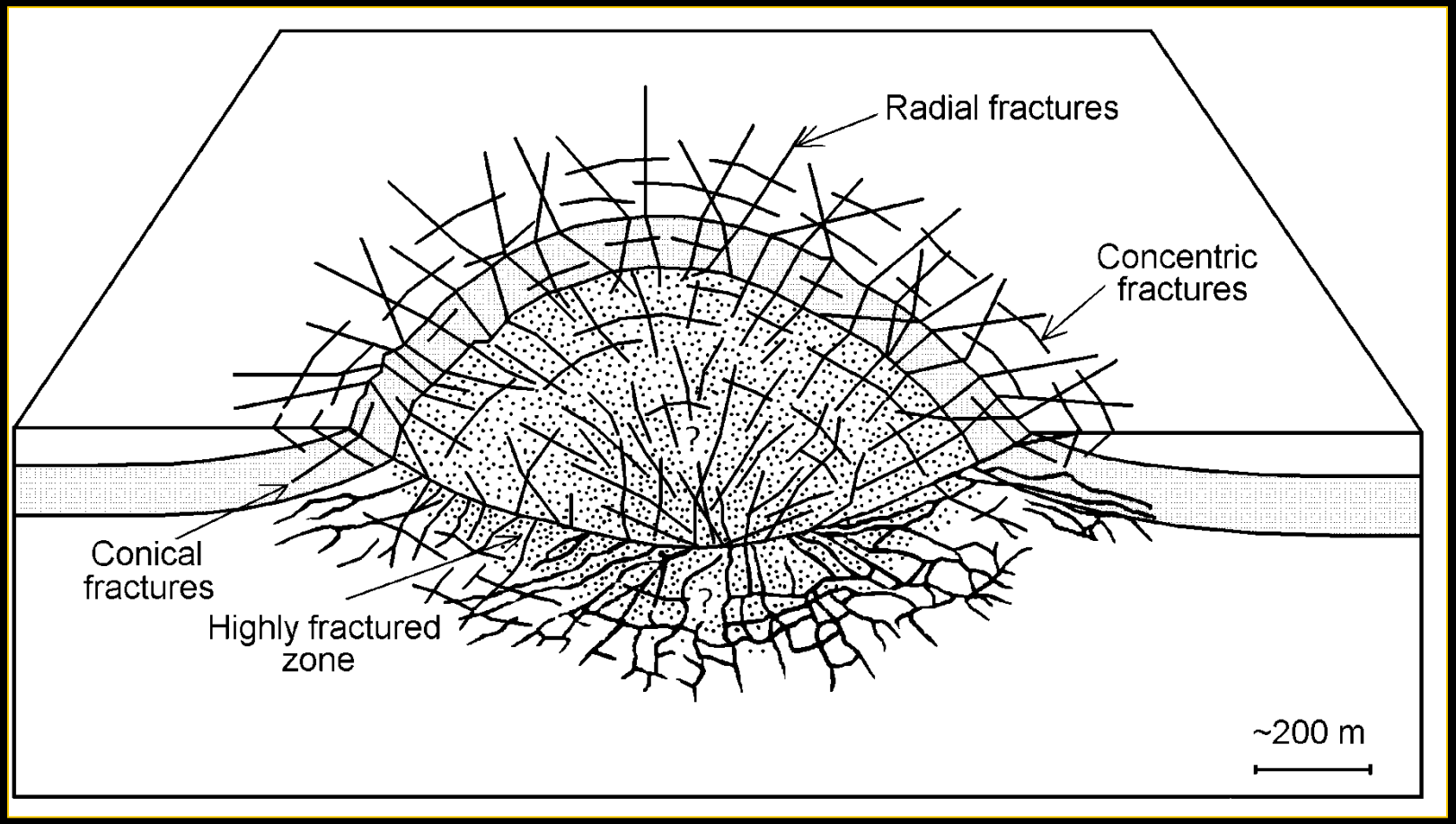
Structural & Stratigraphic Overturning in Crater Rim

Radial, Conical, & Concentric Fracturing of Crater Walls



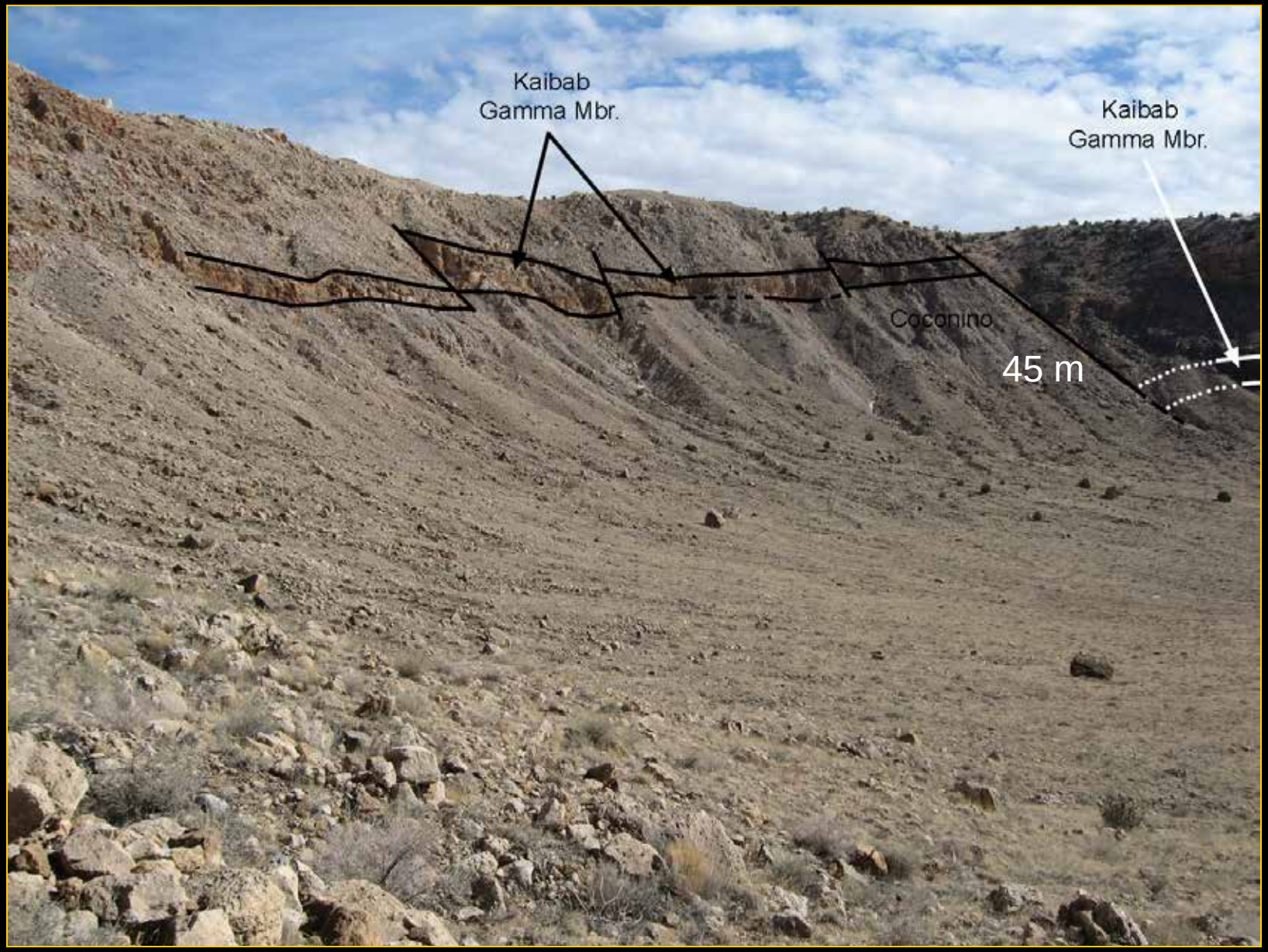
Kumar & Kring (2008)

Radial, Conical, & Concentric Fracturing of Crater Walls



Kumar & Kring (2008)

Differential Uplift Along Sub-Vertical Faults

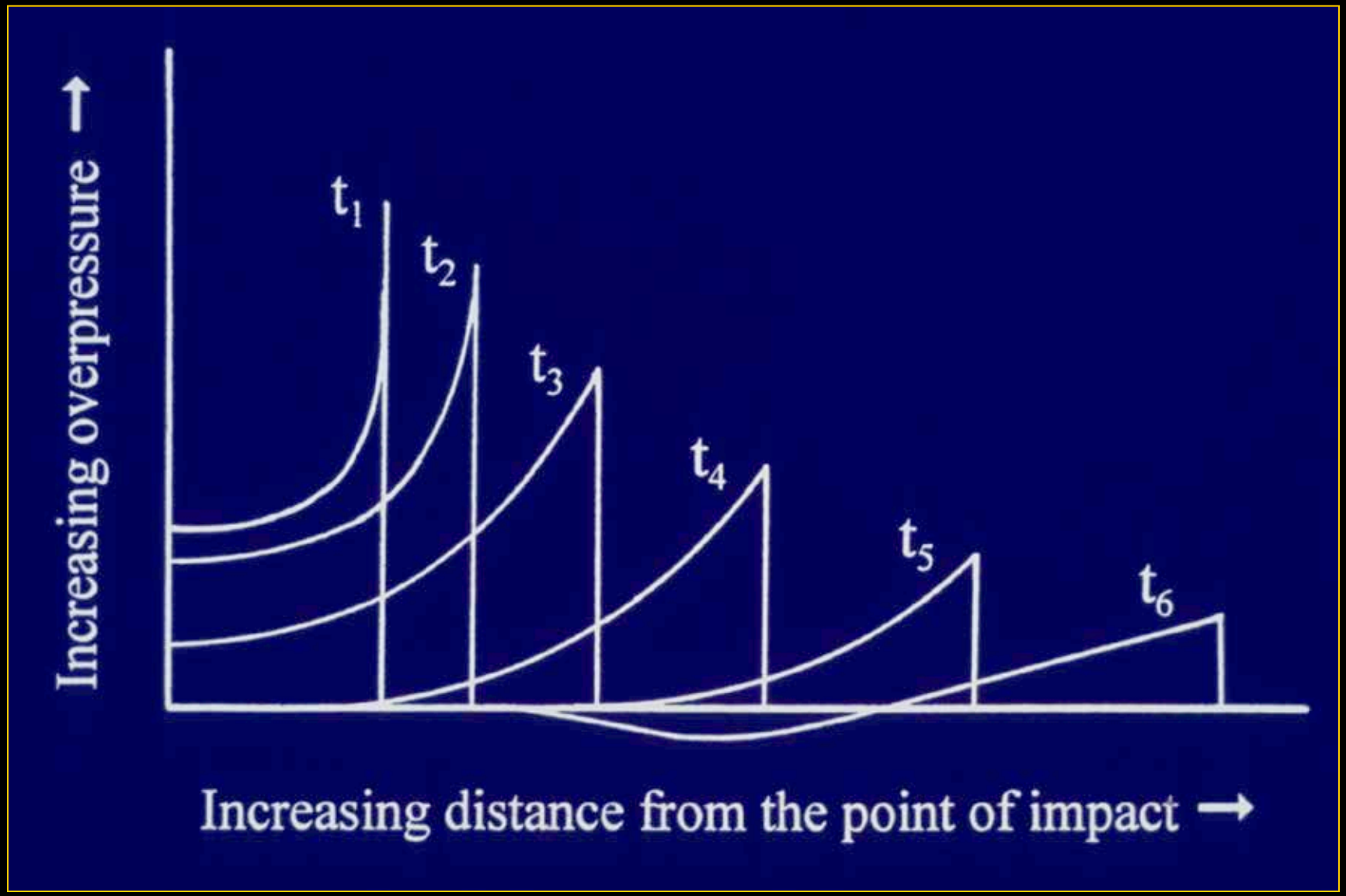


Estimates of Impact Energy

Energy (MT TNT equivalent)	Source
38.3	Magie 1910
38	Moulton
2.91	Moulton
0.21	Wylie 1943
0.08	Baldwin 1949
4.8	Gilvany and Hill 1956
64	Opik 1958
1.4 to 1.8	Shoemaker 1963
8.1	Baldwin 1963
4 to 5	Shoemaker 1974
22 to 61	Schmidt 1980
15	Roddy et al. 1980
15+	Shoemaker 1987
20 to 40	Roddy and Shoemaker 1995
5.3	Schnabel et al. 1999
0.44	Ai and Ahrens 2004
2.5	Melosh and Collins 2005
10 to 11	Artemieva 2006 (with Pierazzo)

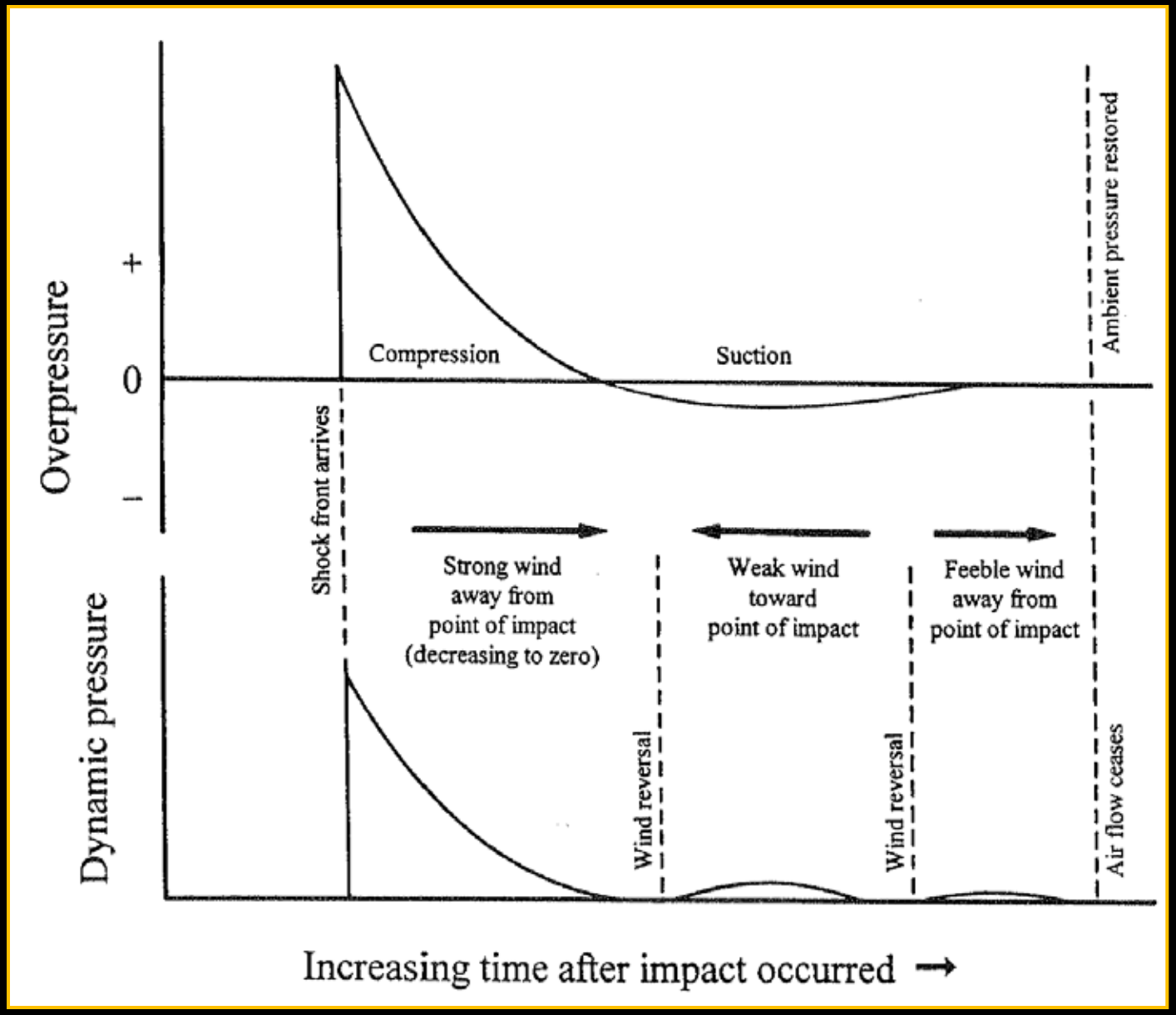
How much energy did it take to process all that rock?

Environmental Effects of Impact Event

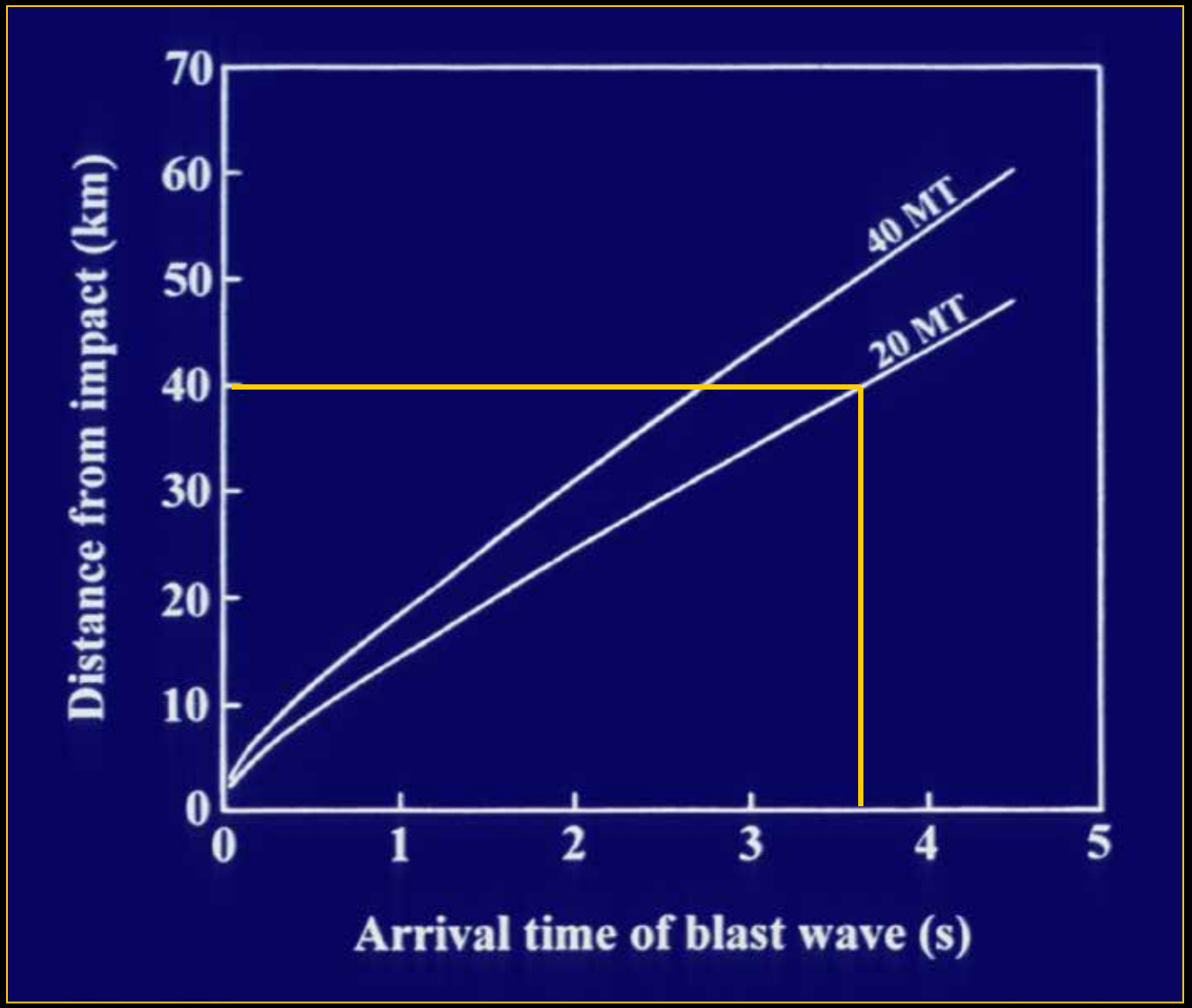


Shock wave radiates across the landscape

Environmental Effects of Impact Event



Environmental Effects of Impact Event



Shock wave radiates across the landscape

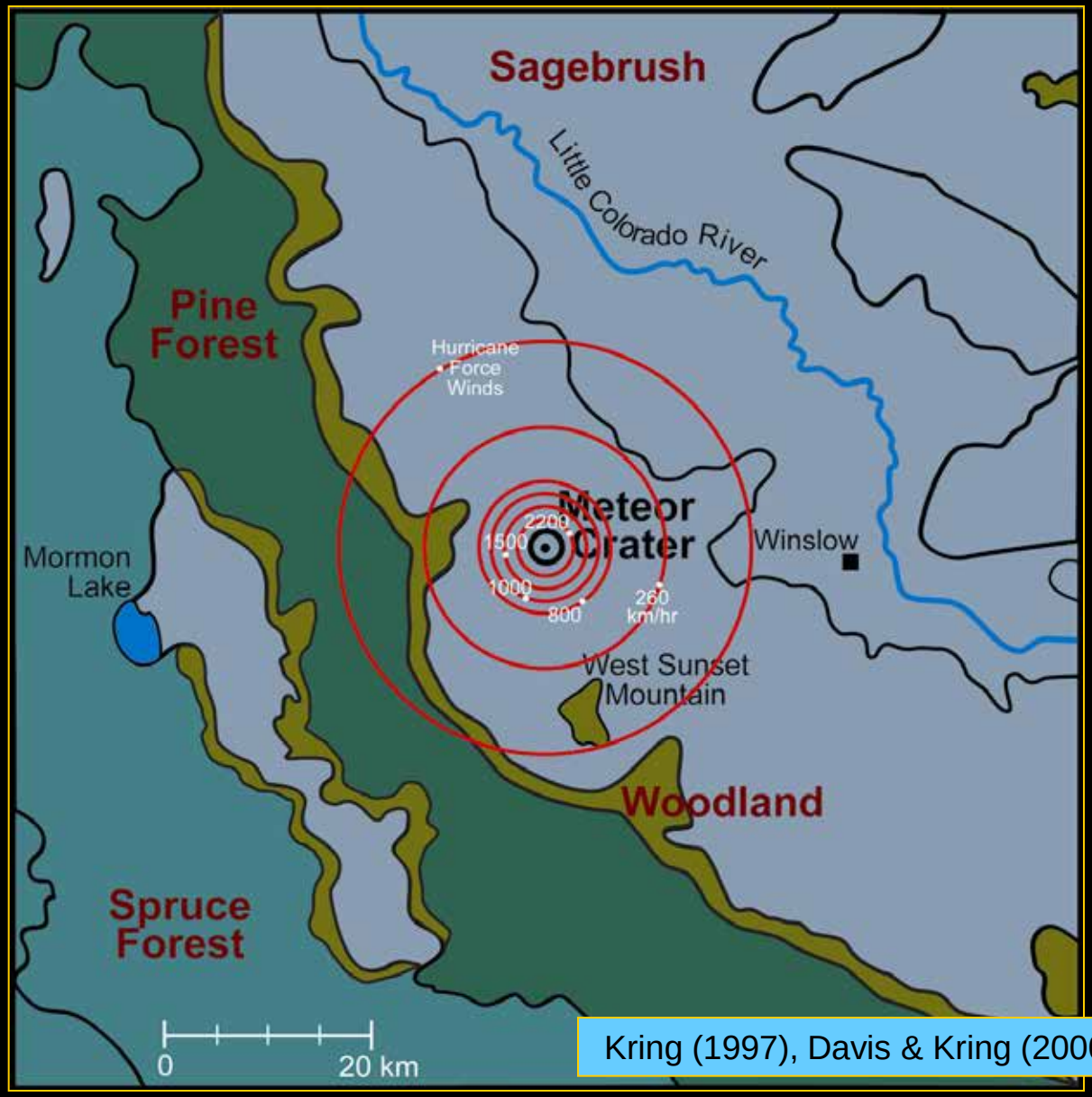
Impact Air Blast

Peak Overpressure (psi)	Wind Velocity (km/hr)	Distance from Impact (km)
		For 20 MT Impact
100	2277	2.8
50	1503	3.8
30	1077	4.9
20	808	5.9
10	473	8.5
5	262	12
2	113	21
1	58	32

Environmental Effects of Impact Event

Modern Bio-Zones

Environmental Effects of Impact Event



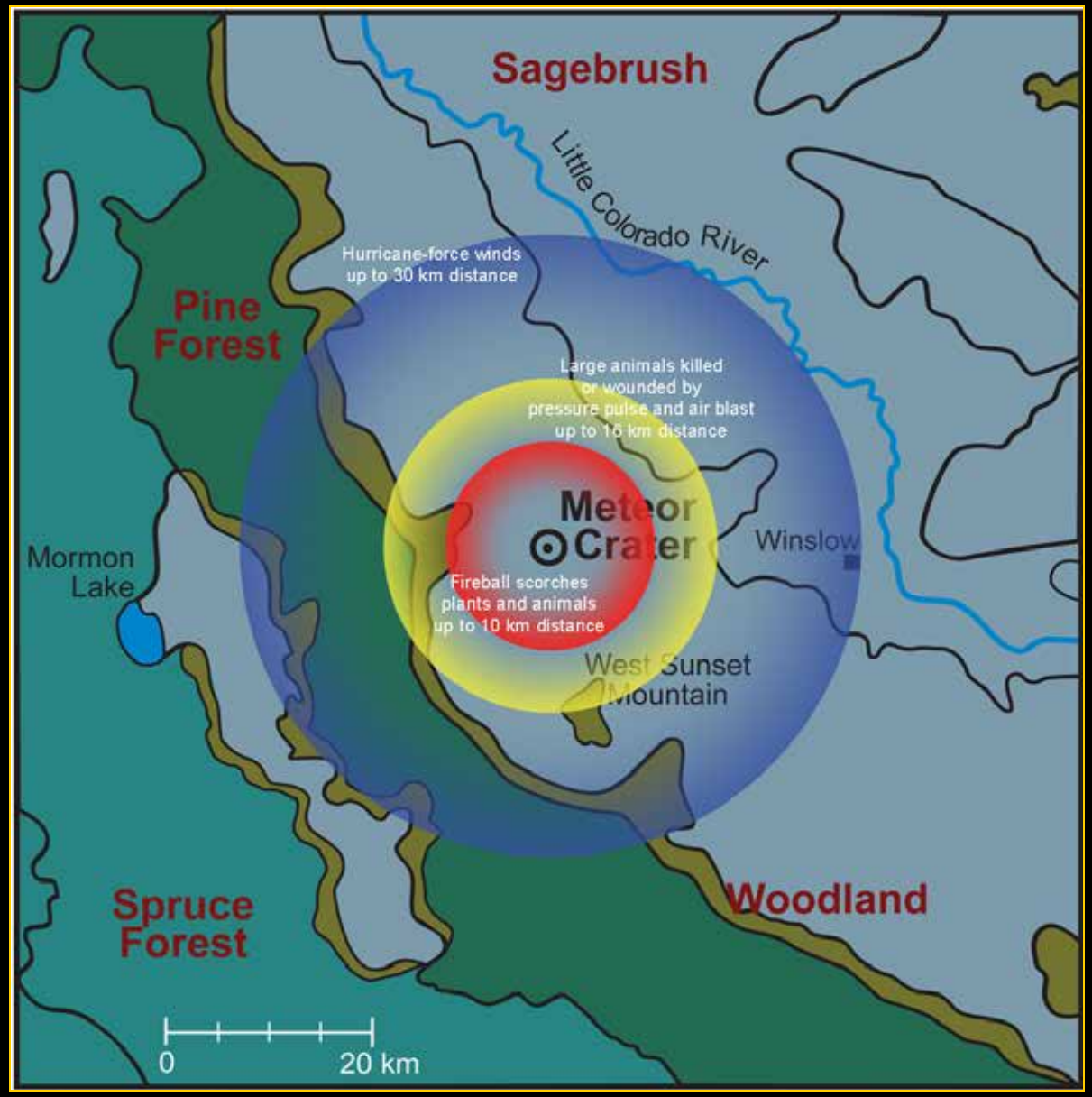
50 ka
Bio-Zones

&

Air Blast
Velocities

Kring (1997), Davis & Kring (2000); Kring (2007)

Environmental Effects of Impact Event



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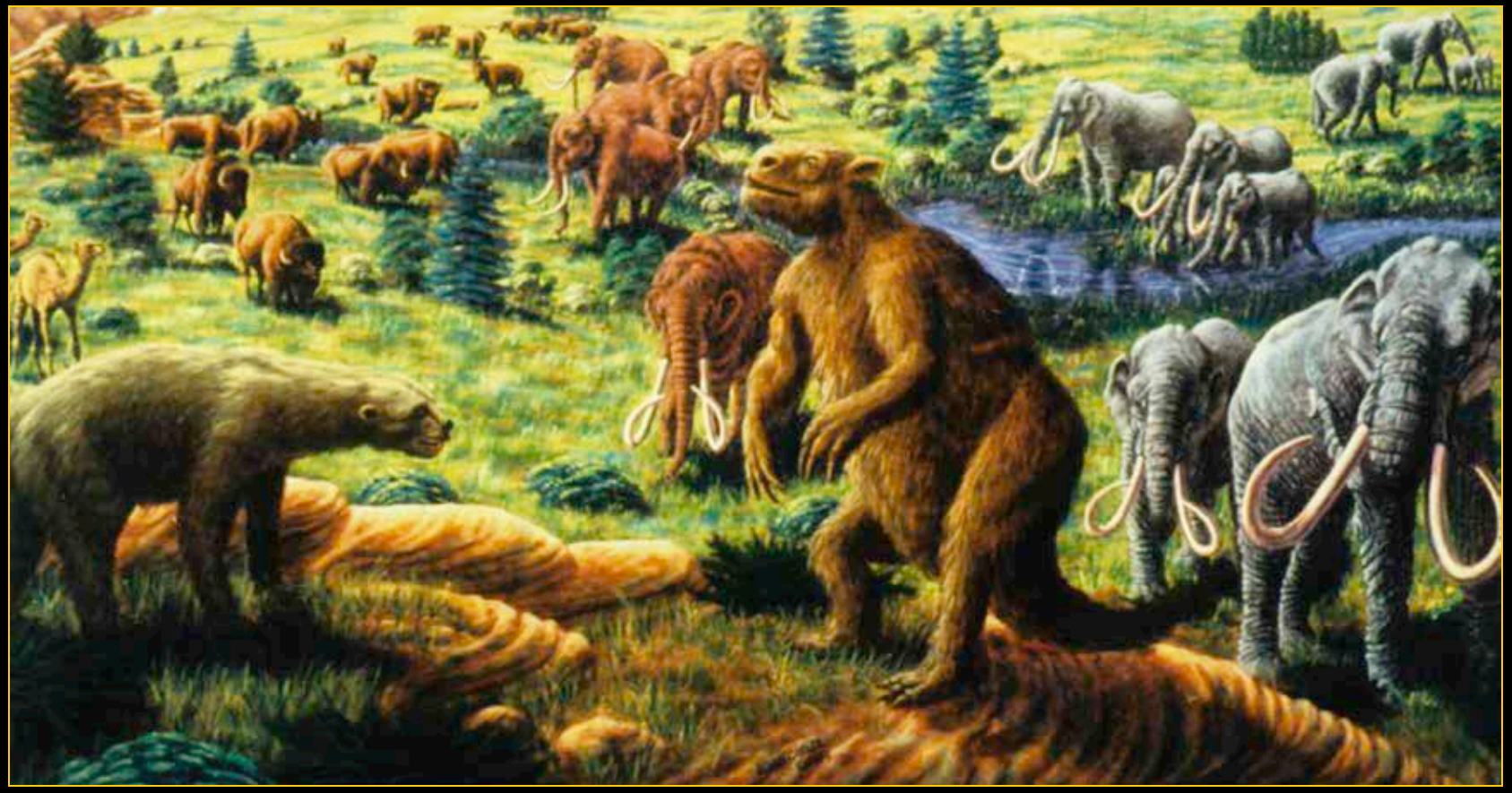
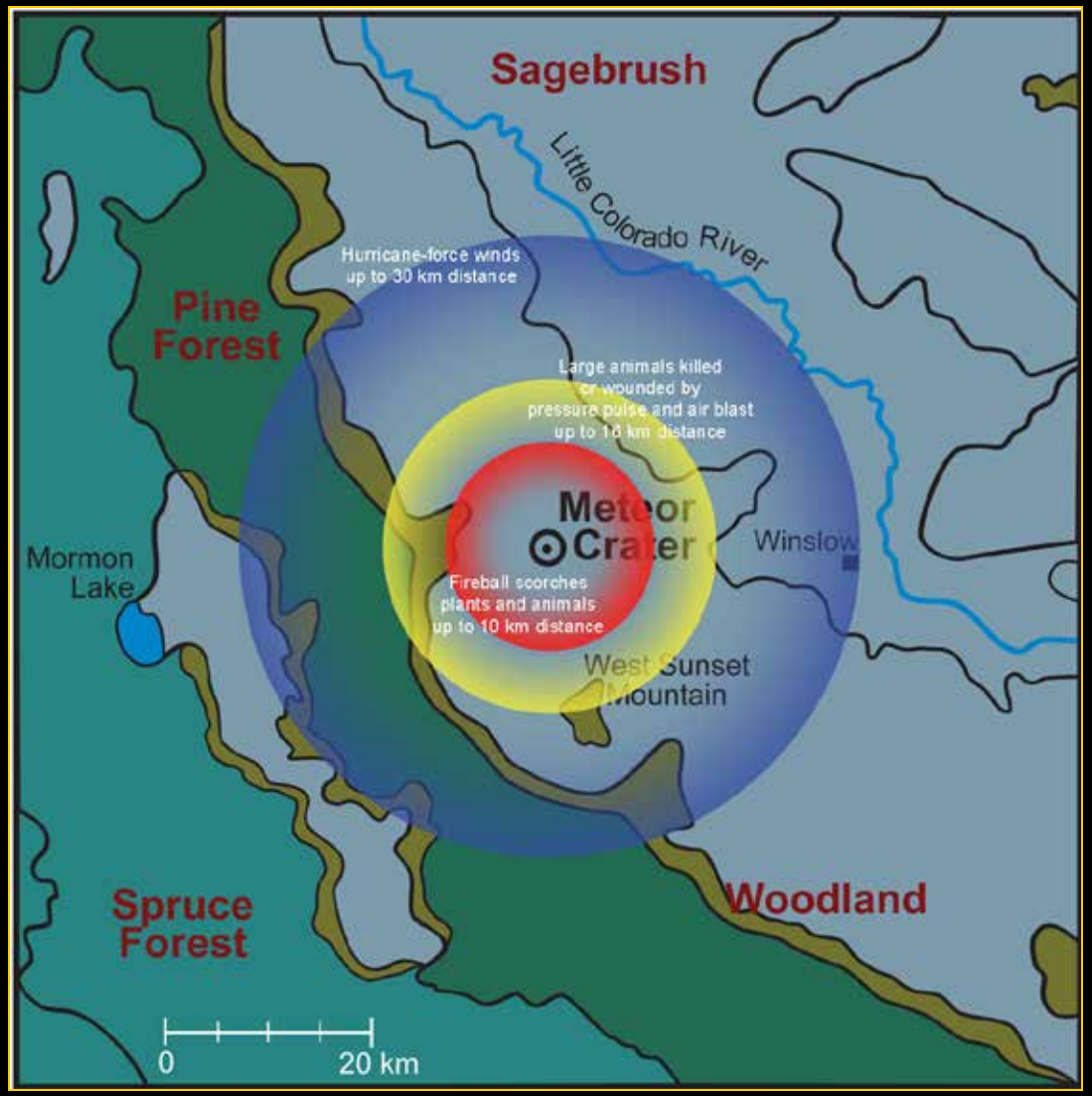


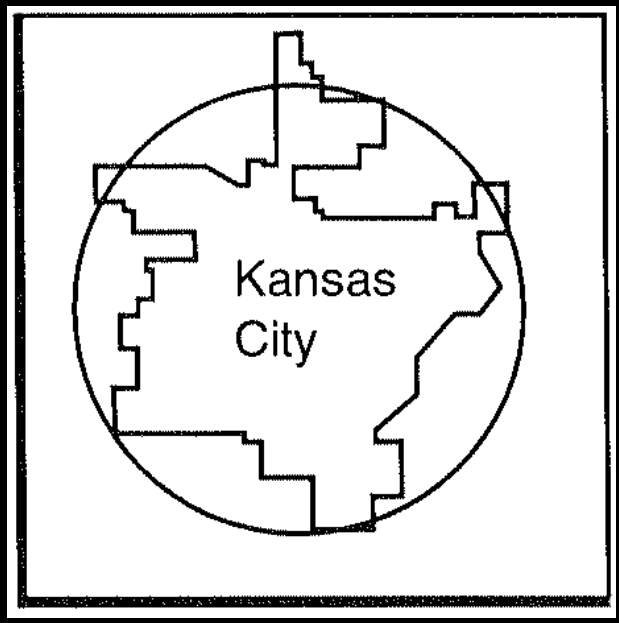
Megafauna that may have existed in a grassland community on the Colorado Plateau 50,000 years ago. From left to right are camels (*Camelops hesternus*), giant short-faced bear (*Arctodus simus*), bison (*Bison bison*), mastodons (*Mammut americanum*), Harlan's ground sloth (*Glassotherium harlani*), and mammoths (*Mammuthus columbi*). Painting by Denny Carley, based on paleontological research by Larry Agenbroad and Jim Mead, appearing in Kring (1997).

Environmental Effects of Impact Event



Small cratering events

Such an event today could decimate the population of an urban area equivalent to the size of Kansas City, U.S.A. (population 425,000).



40 km circle corresponding to severe to moderate damage.

Strength of NEA: Small (<1 km diameter) Impact Pits & Craters

Crater	Locality	Diameter (km)	Projectile	Age (Ma)
Haviland	USA	0.011	Pallasite	0
Dalgaranga	Australia	0.021	Mesosiderite	0.025
Sikhote Alin	Russia	0.027	IIAB	0
Campo del Cielo*	Argentina	0.05	IAB	<0.004
Sobolev	Russia	0.053	Iron	0
Veevers	Australia	0.08	IIAB	<1
Ilmenetsa	Estonia	0.08	?	>0.002
Wabar	Saudi Arabia	0.097	IIIAB	0.006
Morasko	Poland	0.1	IAB	0.01
Kaalijarvi	Estonia	0.11	IAB	0.004
Henbury*	Australia	0.157	IIIAB	<0.005
Odessa*	USA	0.168	IAB	0.063
Boxhole	Australia	0.17	IIIAB	0.03
Macha	Russia	0.3	Iron	<0.007
Aouelloul	Mauritania	0.39	Iron or Pal	3.1
Amguid	Algeria	0.45	?	<0.1
Monturaqui	Chile	0.46	IAB	<1
Kalkkop	South Africa	0.64	?	<1.8
Wolfe Creek	Australia	0.87	IIIAB	<0.3
Tswaing	South Africa	1.13	Chondrite	0.220
Barringer	USA	1.19	IAB	~50

*Crater field; the diameter of the largest crater is listed.
Does not include the ~100 IAB meteorite falls that were too small to create craters.

Prevalence of Type IAB Iron NEA

Crater	Locality	Diameter (km)	Projectile	Age (ka)
Campo del Cielo*	Argentina	0.05	IAB	<4
Morasko*	Poland	0.1	IAB	10
Kaalijarvi*	Estonia	0.11	IAB	4 ± 1
Odessa*	USA	0.168	IAB	~65
Monturaqui	Chile	0.46	IAB	<1000
Barringer	USA	1.19	IAB	~50

*Crater field; the diameter of the largest crater is listed.
Does not include the ~100 IAB meteorite falls that were too small to create craters.

Prevalence of Type IAB Iron NEA

- Barringer Crater, with a diameter of ~1 km, is near the lower limit of hypervelocity impact craters on Earth
- The atmosphere shields the surface from small or weaker NEA
- Because most small craters are produced by iron NEA, they appear to be stronger than stony NEA
- The number of craters produced by type IAB irons, relative to other irons, is higher than the ratio of those objects seen in the smaller meteorite population
  - ~28% of the small crater were produced by type IAB NEA
  - ~40% of craters produced by irons were produced by IAB iron NEA, while only 10% of iron meteorite falls are type IAB

Prevalence of Type IAB Iron NEA

- The data suggest one of three conclusions:
  - Type IAB NEA are stronger than other irons and, thus, better able to penetrate the atmosphere,
  - Type IAB asteroids are less collisionally evolved than other irons and are, thus, less populous among meteorite-size objects, or
  - We are being misled by small number statistics


Questions?