
What is Science?
Fun
Science

Science is an expression of human curiosity and a desire to learn.

1. The world around us.
2. Where we came from.
3. How we got to where we are.
4. Where we might be going in the future.

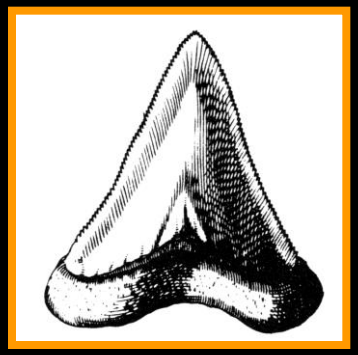
Science is Many Things

1. The pursuit of knowledge for the sake of sheer curiosity.
2. Seeks to organize observable information into testable and predictive explanations of natural phenomena.
3. Insists that our world can be understood.
4. A body of knowledge about the physical world.

Science Reflects Our Desire to Explain the Creatures in Our World

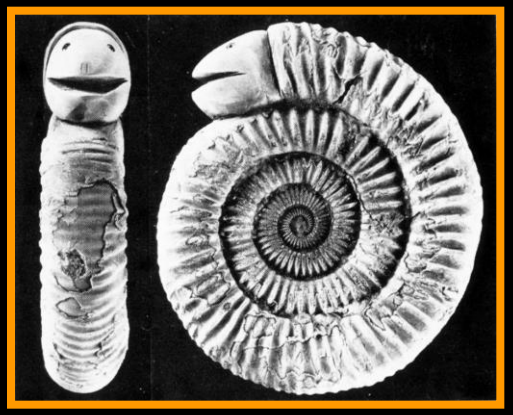
How did these objects form?

Face in the stone



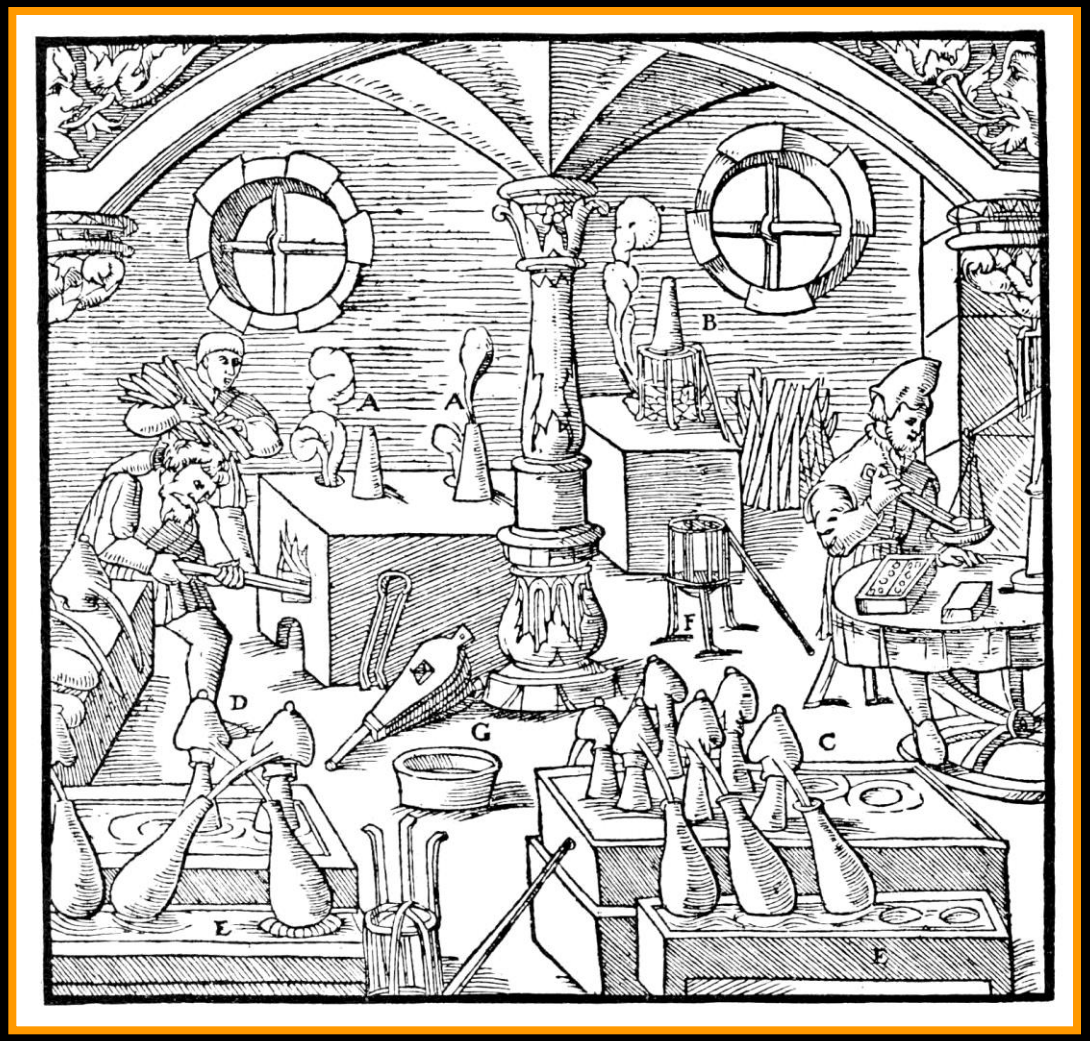
Tonguestone

Petrified thunderbolts



Snakestone

Alchemy & Metallurgy at the End of the Dark Ages



The beginning of empirical science, based on observations and experimentation.

Traits that Characterize a Scientist?

Curiosity.

Imagination and creativity.

Passion for knowledge.

Dedication.

Intellectual honesty.

Open to new ideas.

Healthy dose of skepticism.

May display characteristics of having an “obsessive compulsive disorder”.

What? Where? When? How?

What: refers to the "stuff things are made of.“

Where: refers to everything connected with spatial relationships.

1. Relative position or location.
2. Distribution of the observed phenomena.

When: refers to all the problems associated with the history or timing of the phenomena or events.

How: refers to the way things happen or change; explanation of a phenomenon

Why not, Why?

- Why implies a motive
- Devine direction

Scientific Requirements

Data:

1. There can be no science without observations and experimentation.
2. Observations supply the facts of science, but not the explanation.
3. Making observations and collecting facts are the first and most fundamental activities of science.

Scientific Requirements

Classification of observations and data:

Unrelated facts by themselves, do not provide an explanation of a particular phenomenon.

Observations must be sorted, classified, or graphically represented.

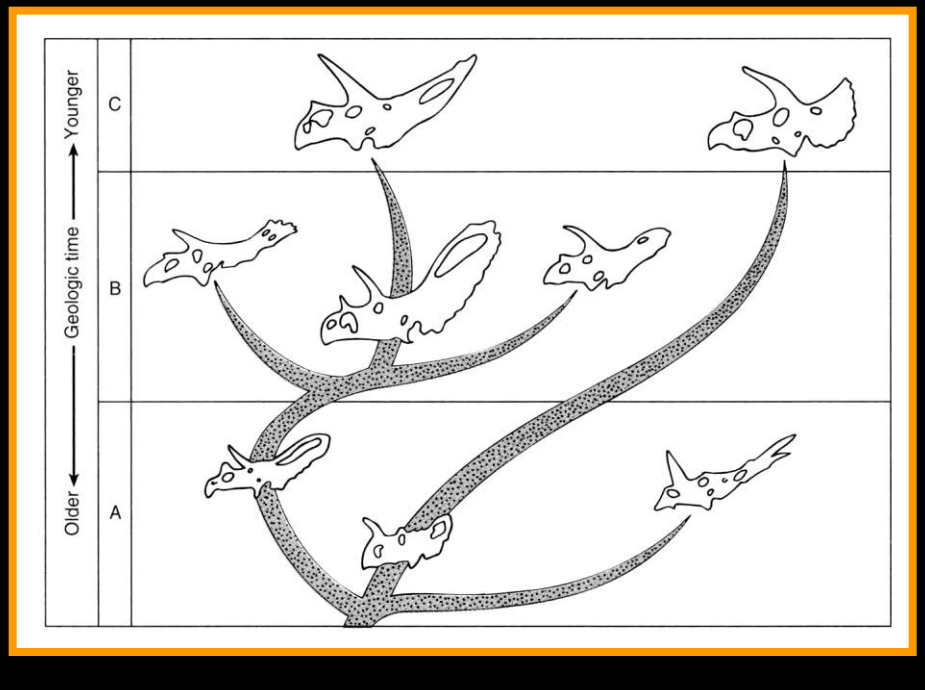
Classification

The manner by which we classify data determines everything in the scientific process that follows.

A number of important scientific discoveries have been made when new classification schemes emerge.

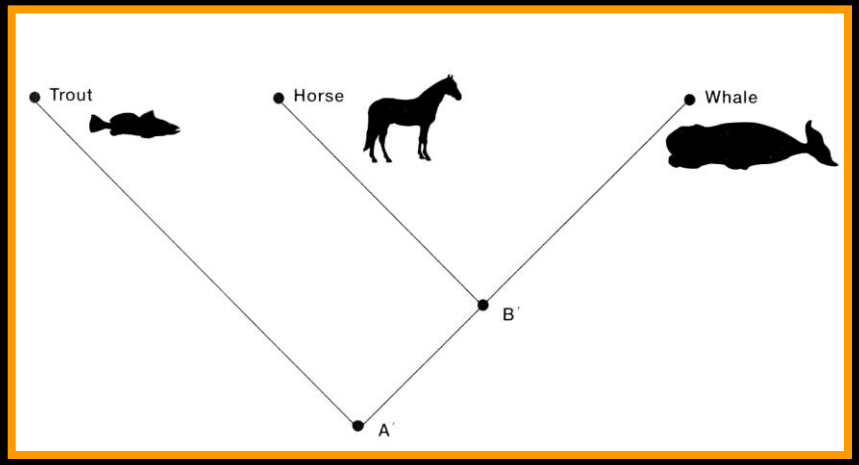
Stratophentic vs. Cladistical Classification

Stratophentic Classification



Based on morphologic similarities and geologic time

Cladistical Classification



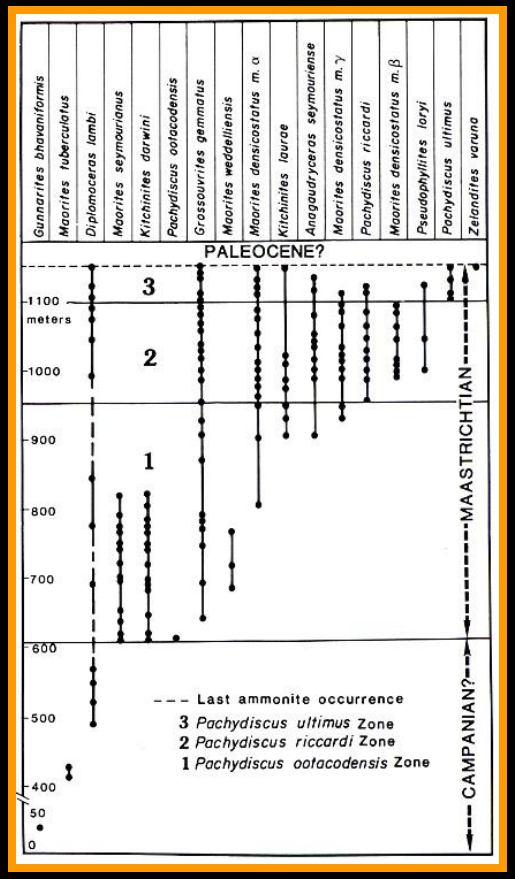
Based solely on "shared characteristics," geologic time plays no role.

Graphical Presentation

Computer technology has greatly enhanced graphical presentation of data.

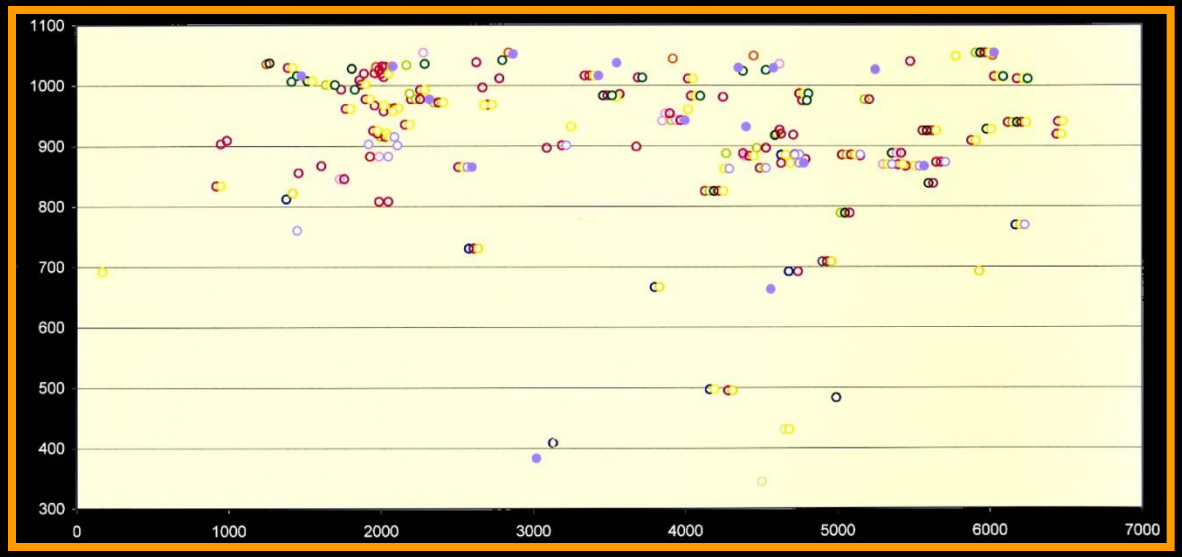
The way in which graphical data is presented can be a highlight or conceal important relationships.

Graphical Projections of Paleontolgic Range Data



Time

Traditional one-dimensional projection of range data



Time

Geographic component

New two-dimensional projection of range data based on both time and geographic component

Scientific Method

Scientific method consists of:

1. **Collection of facts (data).**
2. **Classification of data.**
3. **Formulation of a hypothesis.**
4. **Testing of the hypothesis.**
5. **Recognition of a theory.**

Testing the Hypothesis

Must be able to test the hypothesis.

Must be able to repeat the test of hypothesis by other investigators in other laboratory settings.

There is No Single Approach to the Scientific Method

Each scientific discipline has its own culture.

Scientists approach problems from a variety of viewpoints depending on their scientific discipline.

Where we see different approaches, is in the type of testing of a hypothesis.

Testing the Hypothesis

Bio/medical disciplines

Design an experiment

Determine an experimental method or means of testing the hypothesis.

When designing the experiment, it is important to maintain a control group for comparison with the observed experimental results.

Other Approaches to the Testing of the Hypothesis

Check the original data (repeatable).

Collect additional data.

Develop additional lines or types of data to support the hypothesis.

Incorporate the hypothesis into your own research, but you want to test it to see that it is correct.

Attempt to disprove the hypothesis.

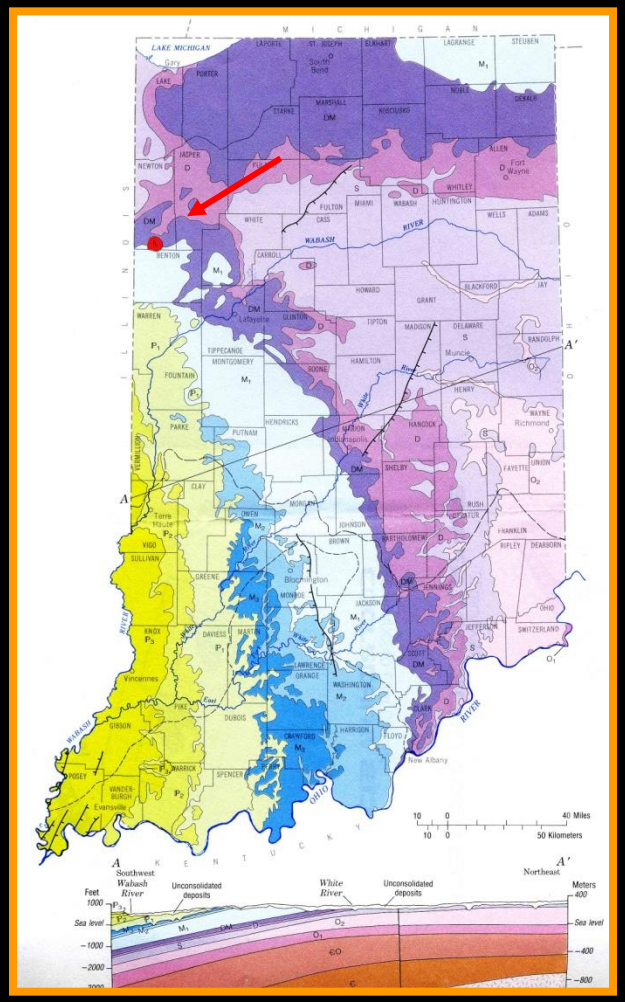
Multiple Working Hypotheses

Initially there may be more than one acceptable explanation of a phenomenon based on the available data.

Additional data and experimentation will lead to the elimination of incorrect explanations.

“Kentland Disturbance”

Highly deformed bedding in the Kentland quarry



Geologic map of Indiana

Normal orientation of bedding

Steeply inclined bedding

Vertical beds

Kentland Disturbance

Observations:

- Small area (2 miles across) of highly deformed rocks surrounded by horizontal rocks.
- Lower Ordovician rocks which are normally1000 feet below the surface, occur at the surface as deformed rocks.

Question: What caused the highly deformed rock structures at Kentland?

Multiple Working Hypotheses for the Formation of the Kentland Disturbance

- Tectonic disturbance.
- Volcanic event.
- Crypto-volcanic explosion.
- Impact event.

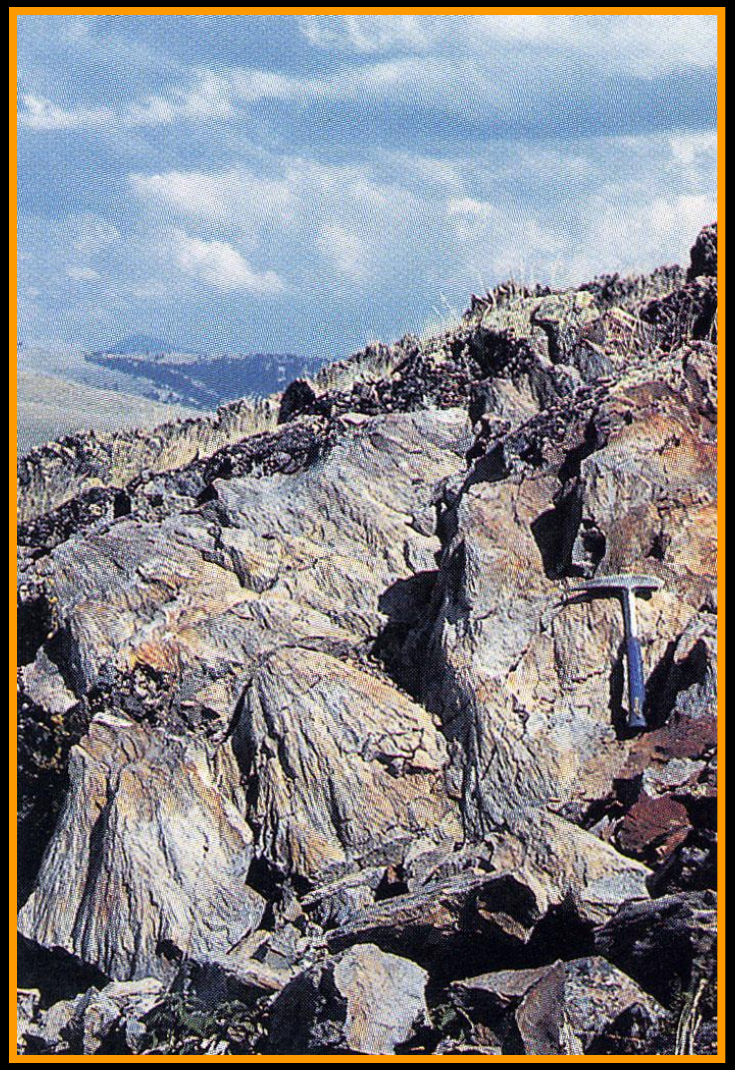
Testing the Hypotheses

- **Additional field work (Testing hypothesis):**
  - **No volcanic rocks present.**
  - **No evidence of intense heating or baking of rocks.**
  - **Evidence of extreme pressure.**

    Intense shattering of, not only rocks, but the grains that form the rocks.

    1. **Formation of shatter cones (pressure fracturing phenomenon), some reaching 6’ in diameter.**
    2. **Quartz grains in sandstones are characterized by parallel laminations (pressure fracturing phenomenon).**

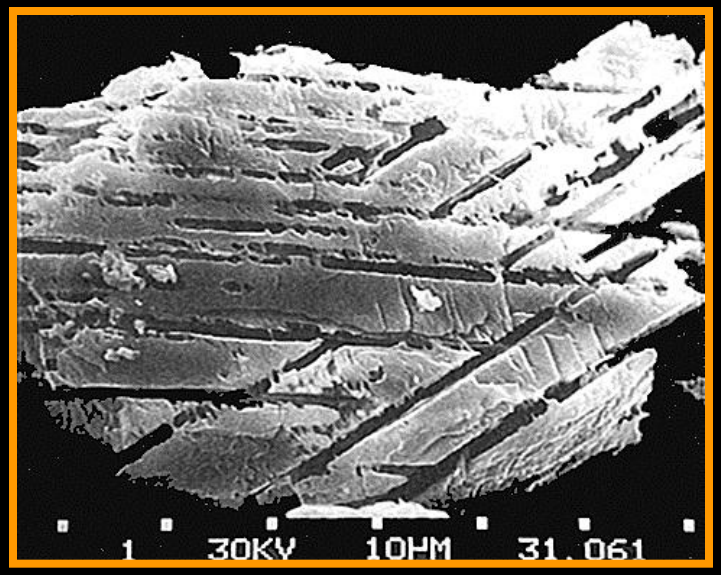
Shatter Cones



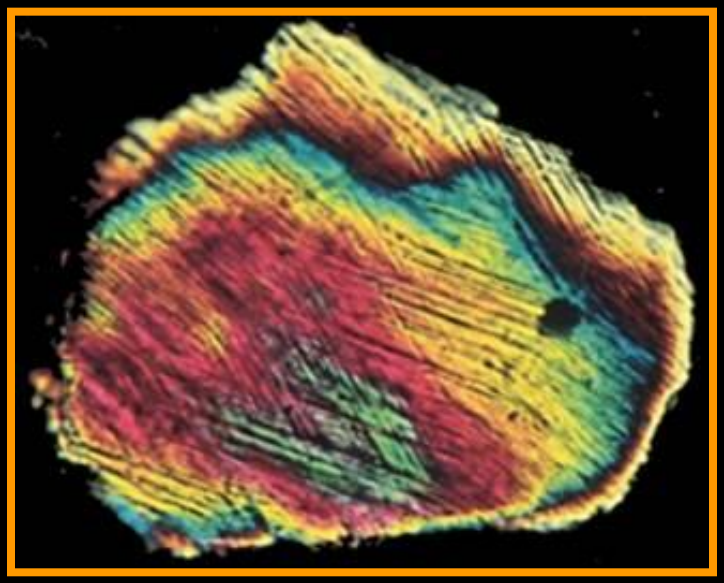
Can only be formed under intense pressure

Shocked Quartz

Laminar fracture pattern in quartz grains



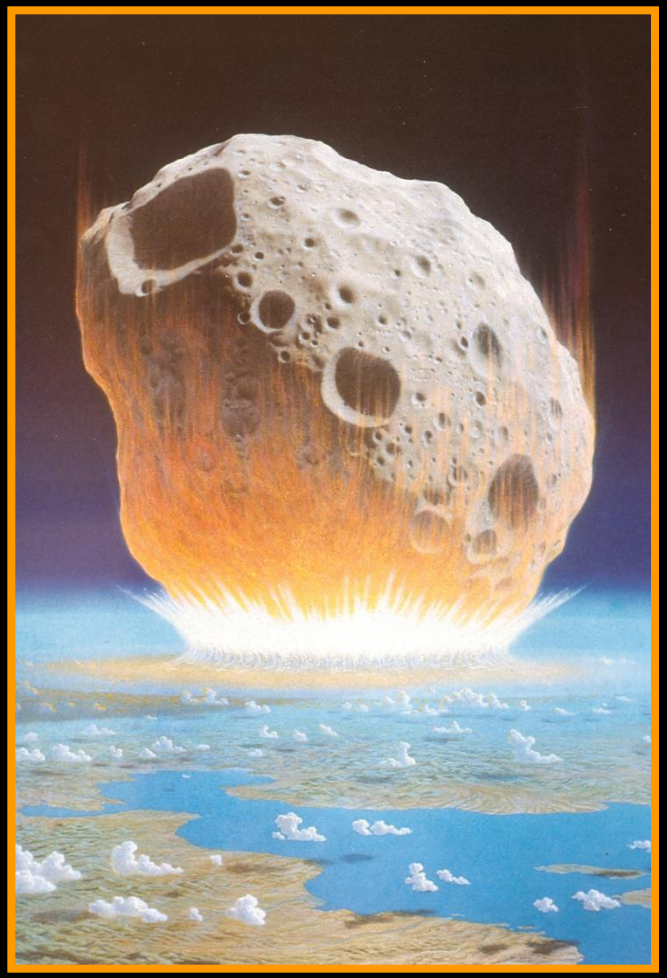
Etched quartz grain



Quartz grain under polarized light

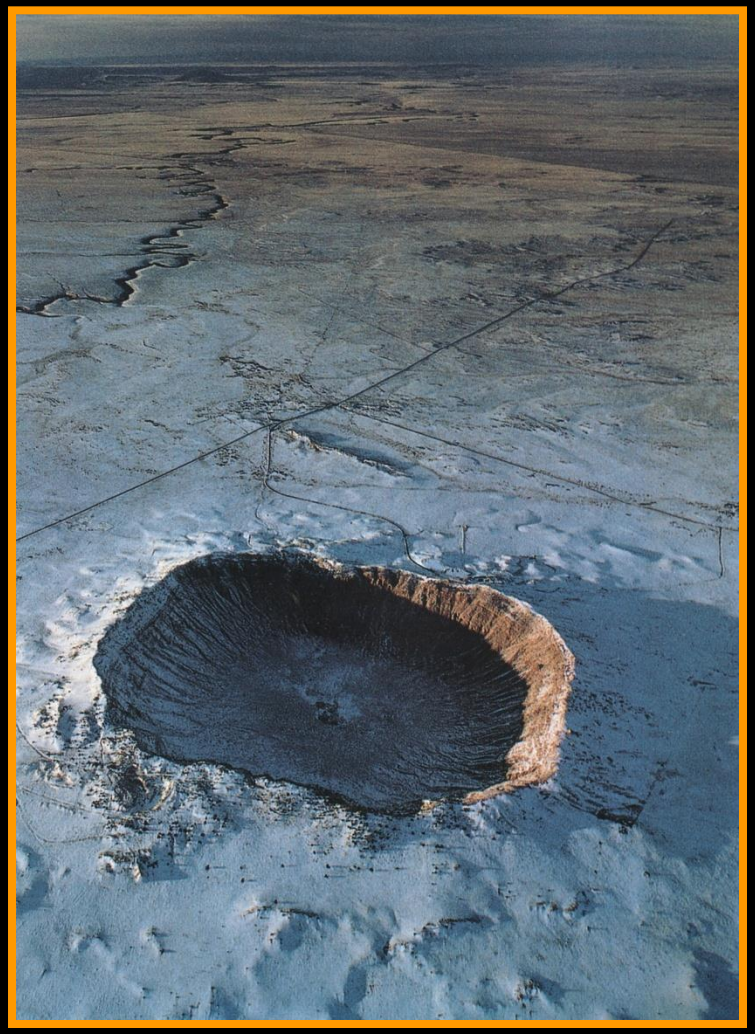
Can only be formed under intense pressure

Kentland Disturbance may have been Formed by an Impact Event



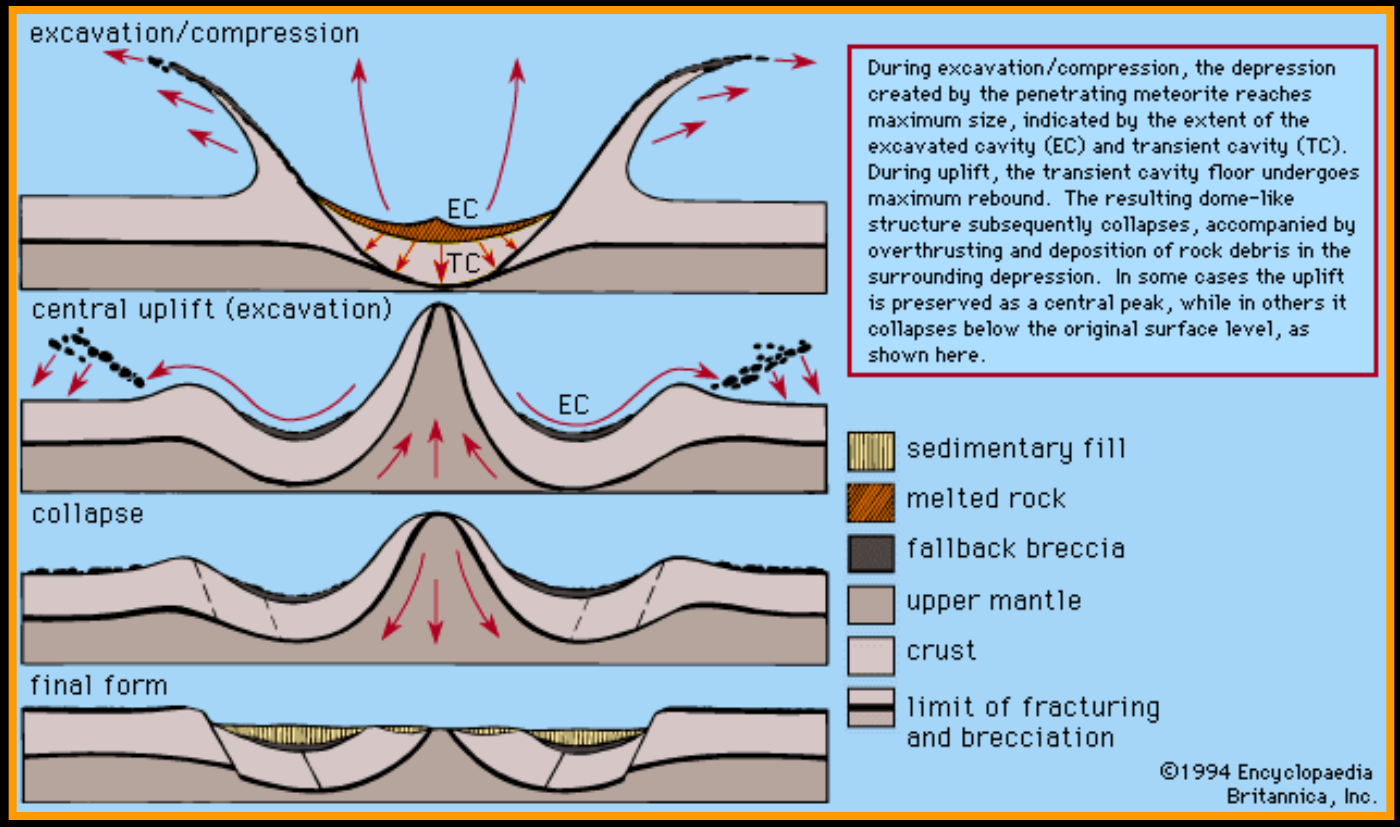
Problems with Impact Hypothesis for “Kentland Disturbance”

Where is the crater or debris from the bollide?

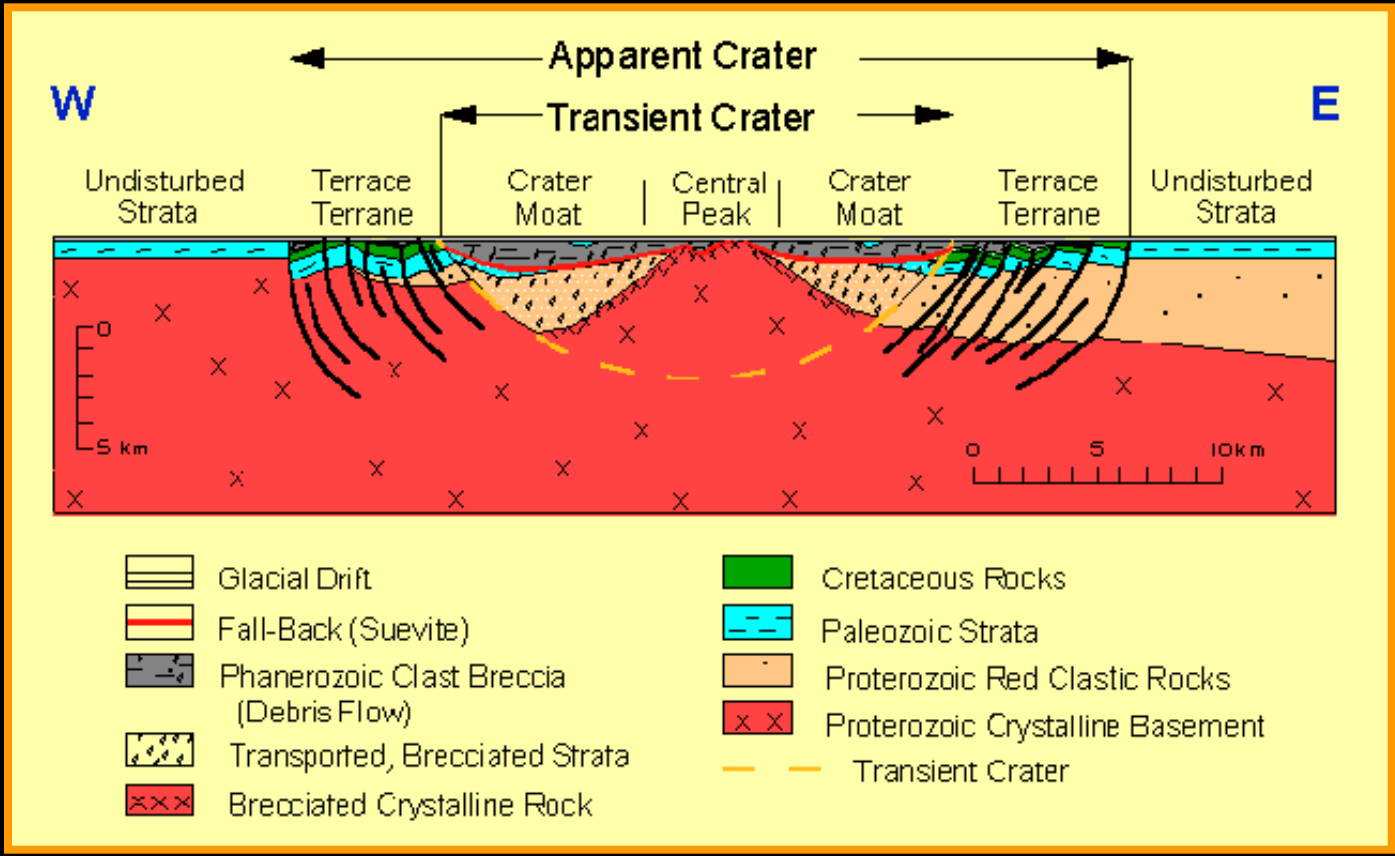


Meteor carter, Arizona

Impact Phenomenon



Recognition of a Theory – Kentland Disturbance was formed by an Impact Event.



Manson crater cross section, Iowa

Crater was destroyed by Late Cenozoic glaciations.

Only deformed rock underlying crater has survived.

Science requires that explanations, hypotheses, and theories be testable.

If an explanation cannot be tested, it is not scientific.

Science is constantly evolving as a consequence of the acquisition of new data.

Traits that may present a scientist with ethical dilemmas regarding their objectivity.

Money - Key to Success in the World of Scientific Research

Dollars are hard to get!

Dollars are needed to conduct research, pay for graduate students, and travel to meetings.

Dollars are needed for promotion, success, and fame.

Dollars are needed for the university.

Enhancing your chances of funding success is never far from your mind.

24/7 Media of the 21st Century

Use of the Media

The media has become a force for good and bad in science.

Benefits:

1. Educates the public.
2. Shows how tax dollars have been used to further knowledge.
3. Positive publicity for institutions (Purdue, NSF, etc).

Use of the Media

Negative aspects:

1. Manipulate the media to support a particular point of view.
2. Use the media to disparage ideas that differ from yours.
3. The media coverage may influence journal reviewers.
4. The media coverage may influence grant reviewers which can enhance or deter funding.

Public & Media do not Understand the Use of Cautious Language by Scientists

Words like "suggests," "may," "could," "might," or other equally fuzzy adjectives are frequently used to:

1. Cover your ass.
2. Promote an idea without solid evidence.

The word may could just as easy be phrased "may or may not" support

Facts, Correlations, Causes

"Avobenzone in sunblock sprays linked to shark attacks"

Causations – a known relationship (cause)

Correlation – necessary property of causation, it does not prove causation by itself.

Can means two things "may" or "may not" be related.

Linked – a convenient term used to imply linked equals causation.

Frequently used to justify sparse evidence

Misinformation vs Disinformation

Misinformation - does not imply dishonest intentions

Disinformation – dishonest intentions

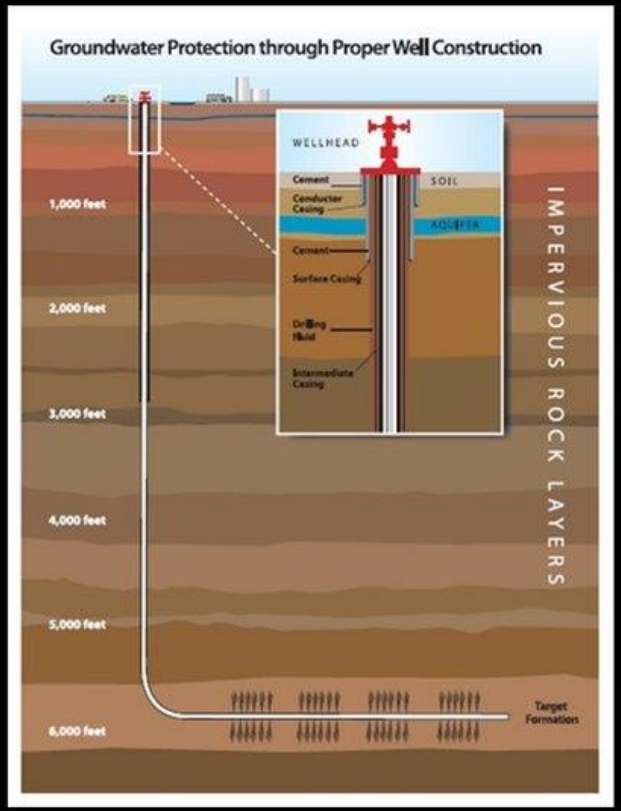
Both terms involve untruths resulting in people believing that the information is true.

Examples:

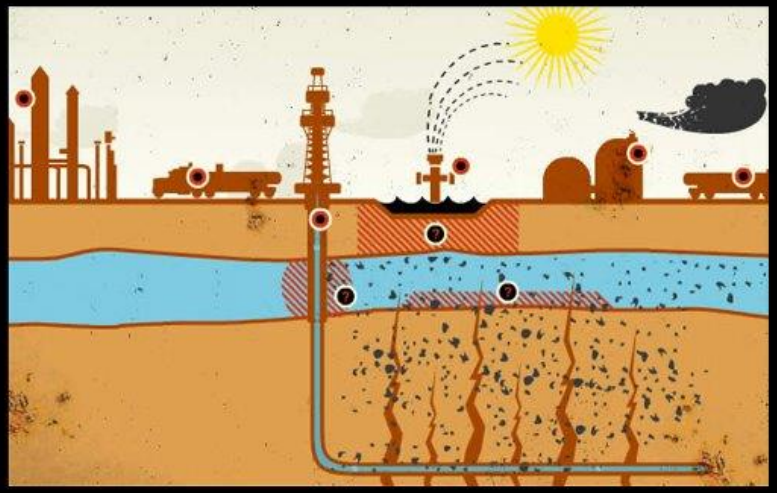
Misinformation - "There is scientific proof that humans are the main cause of climate change."

Disinformation - "Any scientists that receives any funds from industry can not be trusted

Myths versus Facts



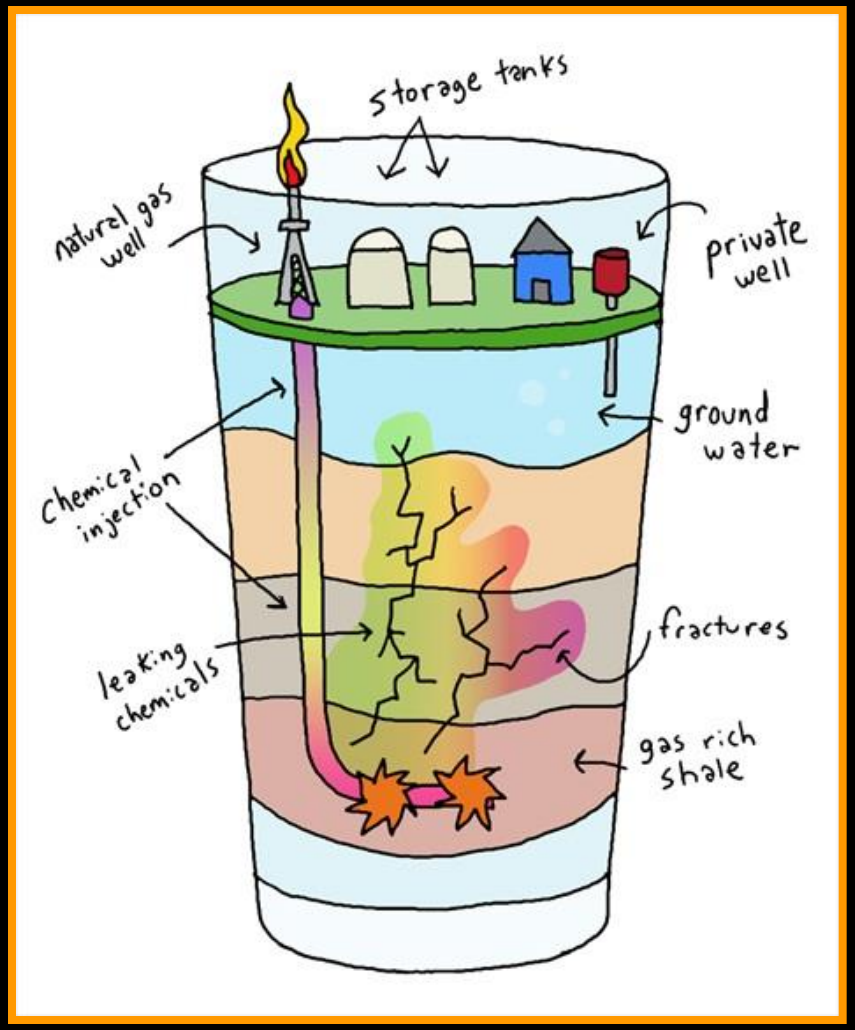
FRACKING: WHAT THEY WANT YOU TO THINK…



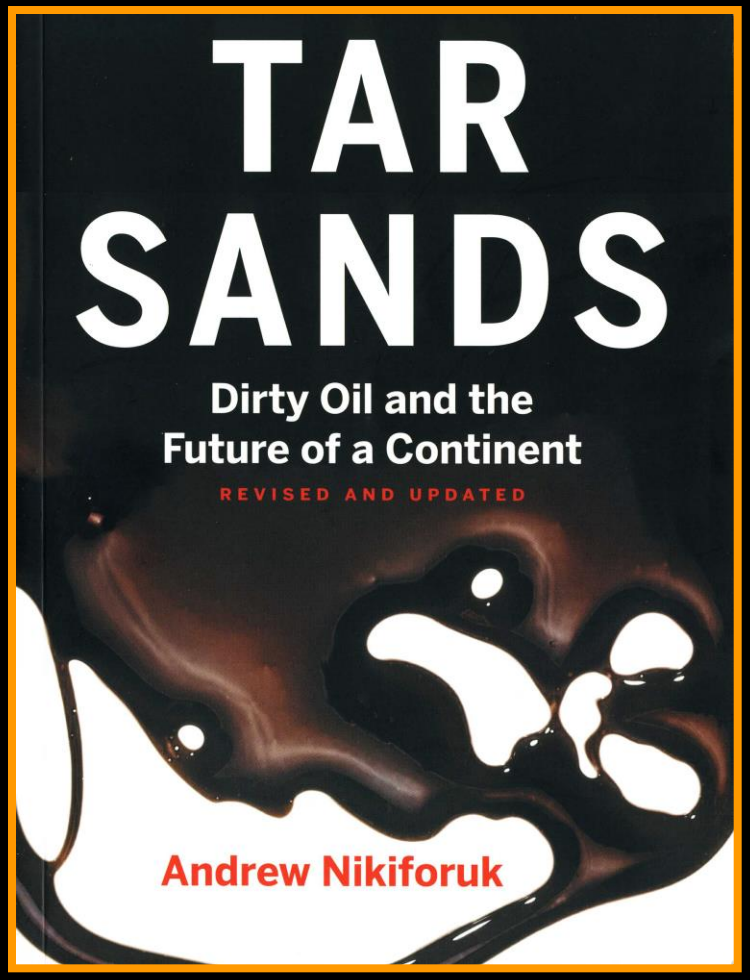
…AND WHAT THEY DON'T!

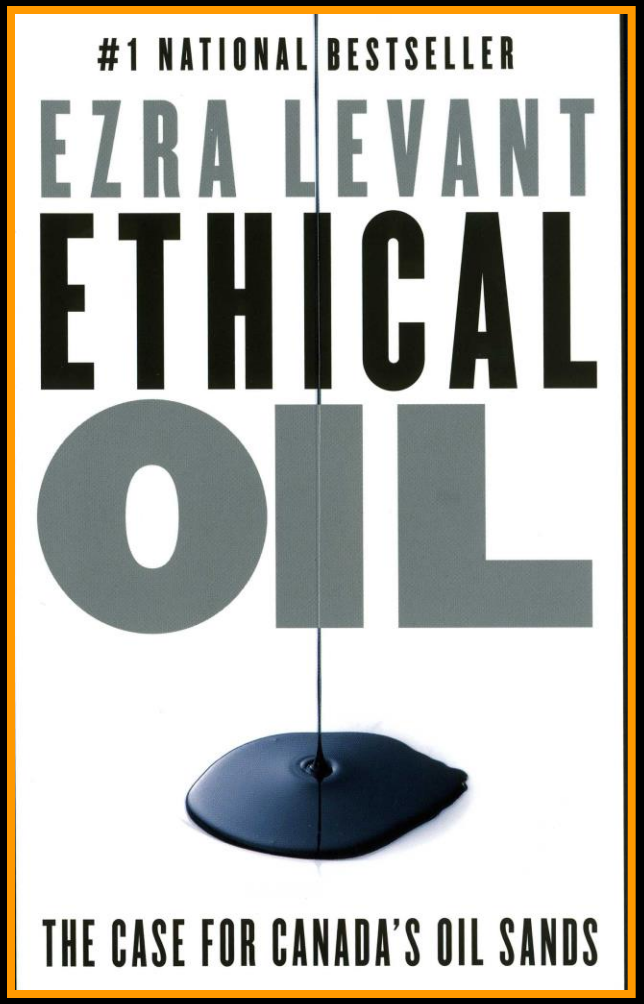
FRACKING IS NOT AN EXACT SCIENCE! IT CAUSES GROUND WATER POLLUTION & AIR POLLUTION & DEGRADATION OF NATURAL LAND & HABITAT DESTRUCTION& TOXIC CONTAMINATION OF SOIL

Beware Figures that are Design that Distort Facts



Beware of Extreme Points of Views





Flaming Water Faucet!

Burning water faucet shown in the documentary Gasland

What questions would you ask?

Predictions

People have been making predictions of the future since time immemorial – haven't been very good at it!

Predictions are not facts.

Some predictions based on scientific principles can be predicted accurately – tides, sunrises, or movement of the planets.

Most future events can not be predicted with any degree of certainty - too many variables.

Complex computer models that predict climatic events 50 to 100 years from now are nowhere as complex as the earth's climatic system – should not be accepted as fact.

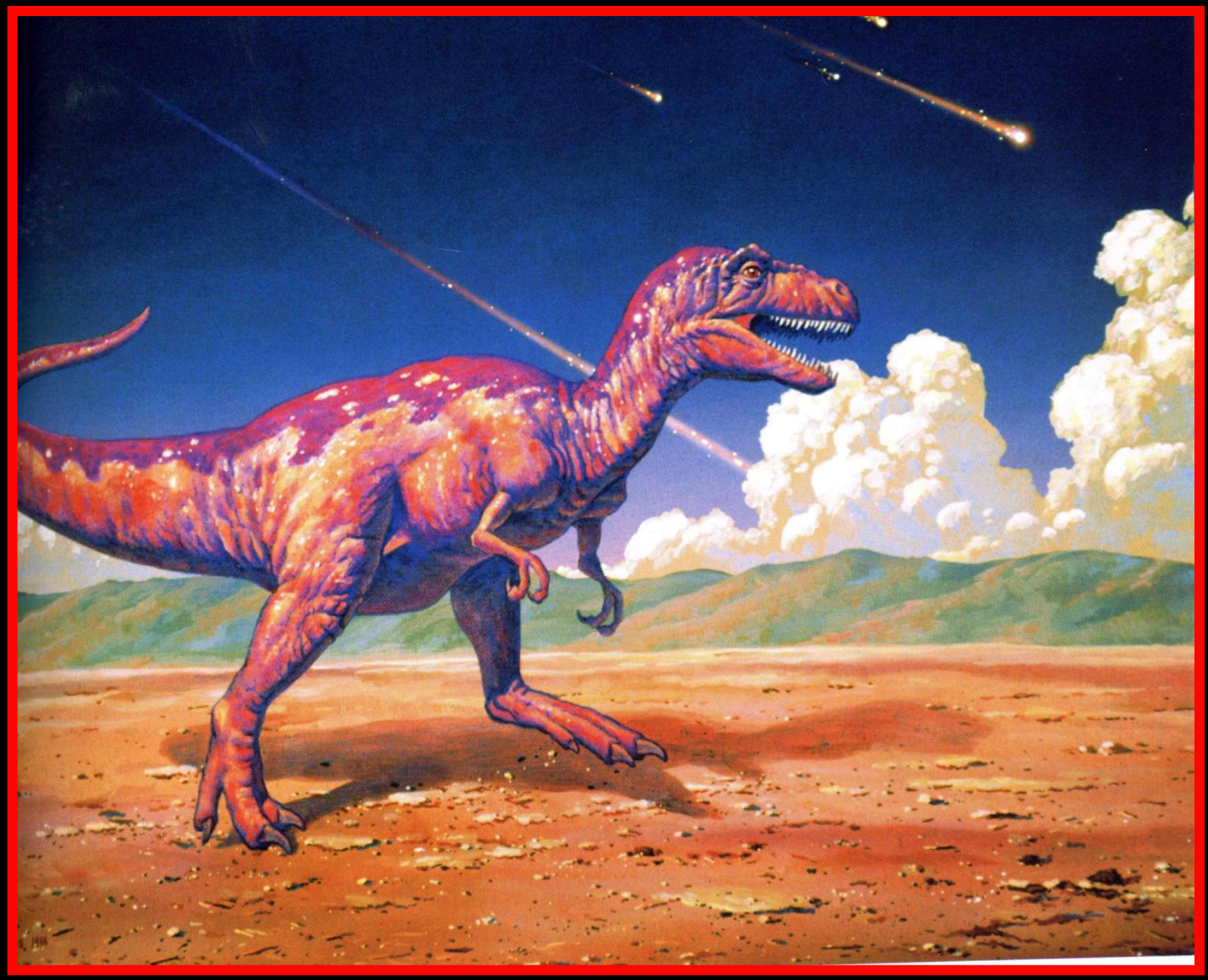
Loss of Objectivity

Openness to new ideas.

Healthy dose of skepticism.

Ability to accept that you may not be right.

Objectivity in Scientific Controversies



Death of the Dinosaurs

Debate Over Dinosaur Extinction Takes an Unusually Rancorous Turn (New York Times, 1/19/88)

- Quotes from Luis Alvarez (Nobel laureate):

On paleontologists:

"I don't like to say bad things about paleontologists, but they're really not very good scientists. They're more like stamp collectors."

Luis Alvarez's questioning of Dr. William Clemens scientific ability:

"…he (Dr. Clemens) is inept at interpreting sedimentary rock strata, and his criticisms can be dismissed on grounds of incompetence."

When politics are introduced into scientific debates there can be profound societal consequences.

Climategate

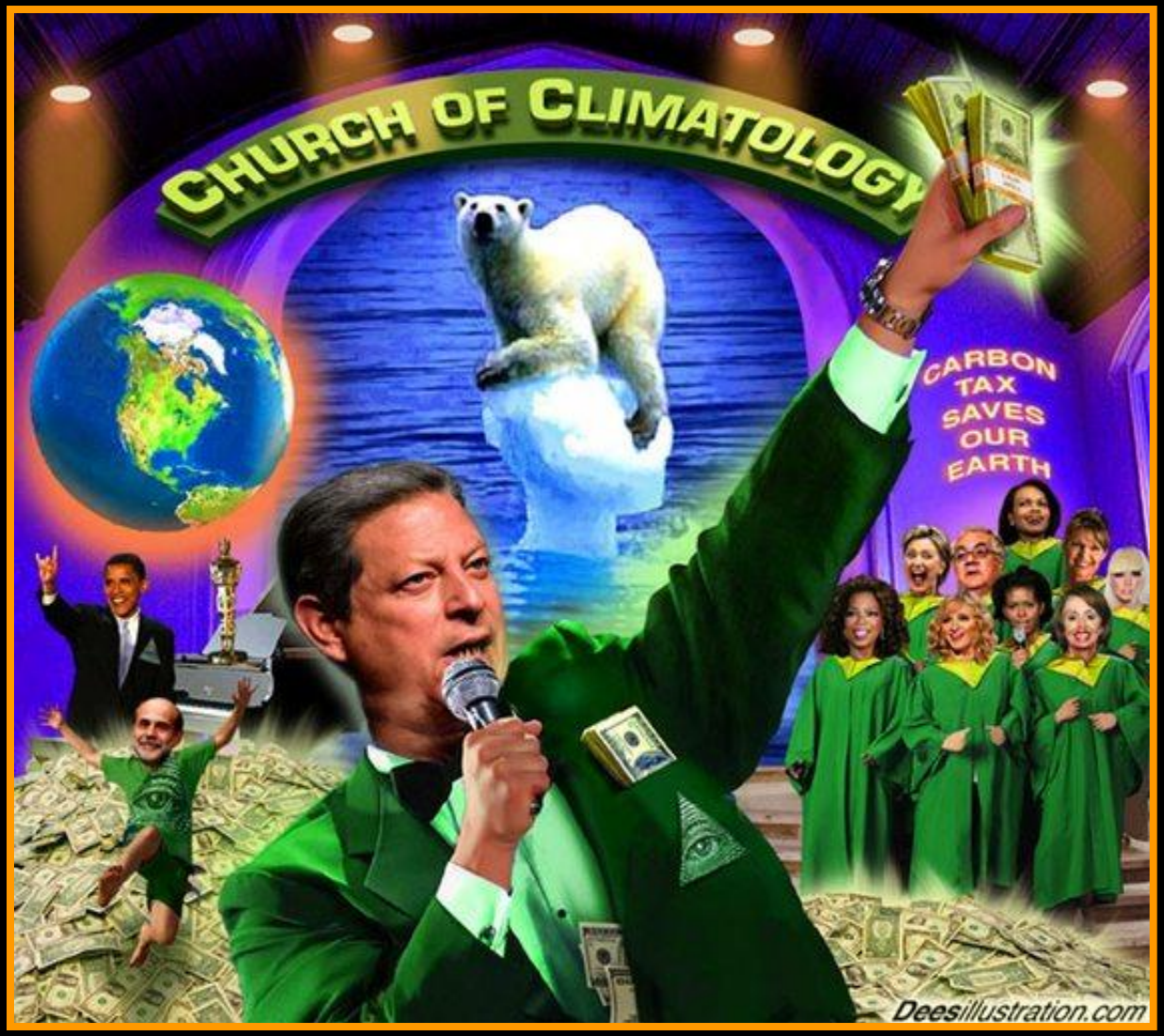
Highly polarized topic allow for no areas of gray.

CRU emails provided insight into the unsavory side of what can happen when some scientists become too emotionally attached to their hypothesis.

Refuse to consider alternative ideas or data that do not support your hypothesis.

Deliberately conceal data.

Emotional attachment to a hypothesis in many cases verge on that found in religious faith



Potential Ethical Dilemmas from Loss of Objectivity

Emotional involvement may affect your objectivity:

- Ignore others work if it does not fit your ideas.
- Impugn the scientific integrity of those who disagree with you.
- Name calling – deniers.
- Intimidation.
- Dismiss ideas from people outside your discipline.
- Unethical use of the media.
- Failure to fairly evaluate or consider alternative ideas, may lead to unanticipated consequences.

Consensus in Science

Recently a number of public figures have used the phrase, "the consensus of scientists support" to support their views on global warming.

What are they trying to accomplish by using the word consensus?

"Mainstream" vs. "Fringes"

Consensus is based on **compromise and negotiations**

Has no place in scientific debates!

Conceal Data

Withholding data from scientists with opposing ideas:

Senior scientist from CRU wrote:

"PS, I'm getting hassled by a couple of people to release the CRU station temperature data. Don't any of you three tell anybody that the UK has a Freedom of Information Act."

Peer Review

Peer review can be used to suppress opposing ideas

Example - CRU email:

I can't see either of these papers being in the next IPPC report. Kevin and I will keep them out somehow – even if we have to redefine what the peer-review literature is."

IPCC's Effort to Deflect Ethical Lapses

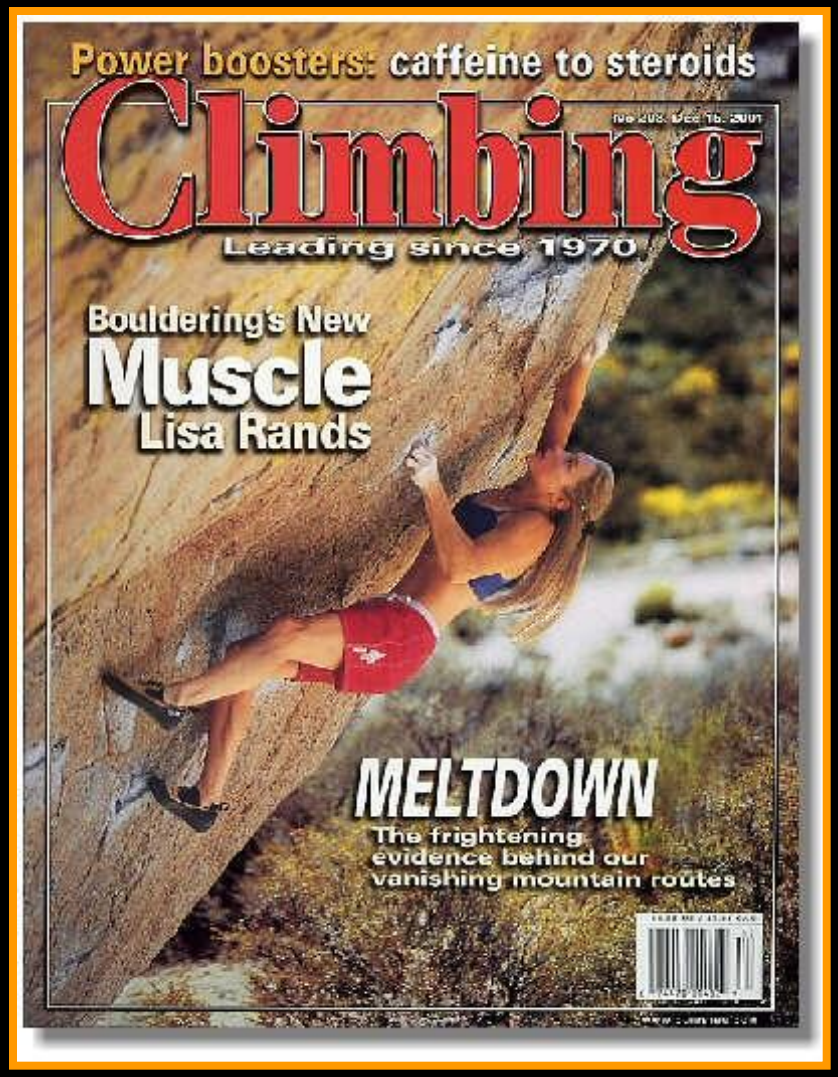
In an effort to play down climategate, the director, Dr. Pachauri of the IPCC Panel released a statement on 11/26/2009 which stated;

"IPCC relies entirely on peer reviewed literature in carrying out its assessments…"

12/04/2009, IPCC website released the same 418 word statement, but with one difference;

"IPCC relies mainly on peer reviewed literature in carrying out its assessments…"

IPCC Panel Cited a Story in "Climbing"



Anecdotal evidence or hearsay

Facts - The Underlying Foundation of Science

"Facts are stubborn things, and whatever may be our wishes, our inclinations, or dictates of our passion, they cannot alter the state of facts and evidence"

John Adams, 1770

Citation of Literature

Data and ideas obtained from other investigators used in any research paper must be cited!

Provides means for the reader to evaluate the quality of the science in the paper.

Failure to adequately cite others work will raise questions.

Types of Scientific Literature

Peered review literature: papers that have been reviewed by qualified outside reviewers.

Gray literature:

- Government reports: may be rigorously reviewed
- Conference & symposium papers: may or may not have been reviewed by outside reviewer.
- Conference abstracts: most never reviewed
- Theses and dissertations (non-published)
- Consulting reports

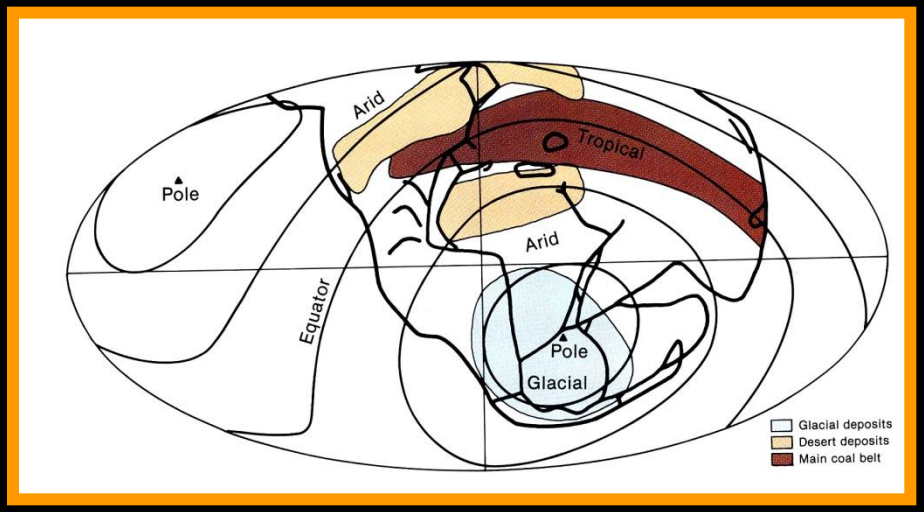
Popular magazines stories - does not rate even as gray literature

Newspaper interviews

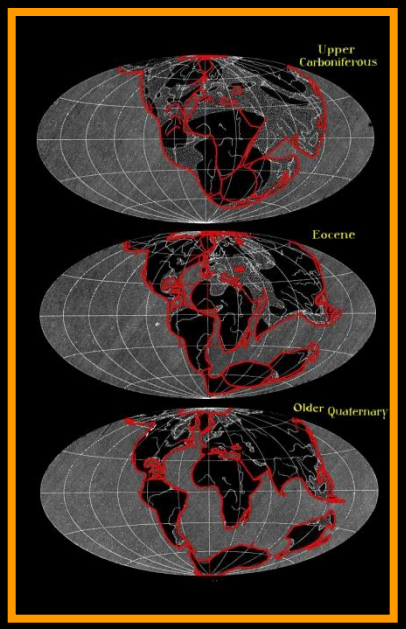
Anecdotal evidence or hearsay

Outsiders have No Business in Scientific Debates

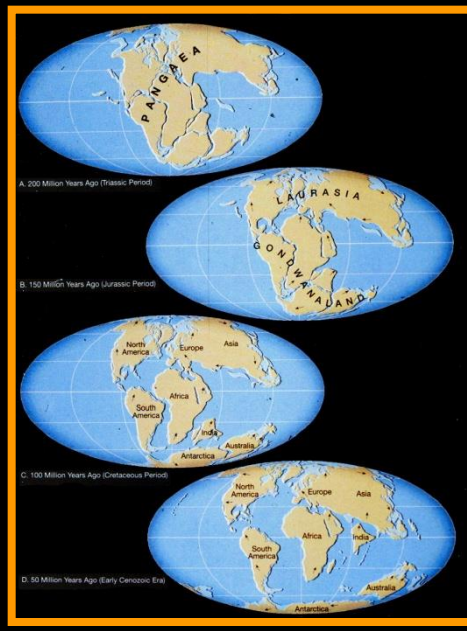
Alfred Wagner's Continental Drift Hypothesis



Distribution of Late Paleozoic Climates



Wagner's drifting continents



Modern view

Internet/Blogosphere Distortions

Internet is filled with distortions and fallacies that are repeated by fellow bloggers.

Bloggers frequently are driven by a certain mindset (group thinking).

A major problem is the detrimental impact that widespread, unsupported views by the blogsphere can affect public policy.

We must respect the right of every individual to hold and express their position.

Degrees of Certainty

Hypothesis: a tentative and speculative explanation advanced for testing.

Theory: an explanation for a phenomenon, which has been well tested and generally agreed upon as an accurate statement of our current understanding of the phenomenon.

Law or Principle: embodies the highest level of confidence, based on having survived numerous episodes of rigorous testing.

Ockham's Razor or Law of Parsimony

In the quest to explain natural phenomena, the simplest explanations are generally the best.

In selecting the correct hypothesis, one should choose the simplest hypothesis.

The Mathematician Jacob Bronowski So Ably Stated:

"Science is a great many things, but in the end... Science is the acceptance of what works and the rejection of what does not."