

Sec.51

RMS Titanic: Why the disaster happen

Unfortunate engineering and safety decisions

Two structural failure theories

Fractured steel hull theory

Charpy impact tests

Brittle-ductile transition temperature

Ultrasound imaging: No large gash

6 narrow slits at collision site

Titanic broke up in half: FEA

Large deformation of hull plates

Missing rivets

Fractured wrought-iron rivet theory

Slag, size, distribution, orientation

Experiments, compare to recovered rivets

Safety lesson

Prescient novel

Titanic, the "Unsinkable", sank on 14 Apr 1912, in less than 3 hours



<http://ultimatetitanic.com/the-sinking/>

"Deeply regret advise you TITANIC sank this morning after collision with iceberg, resulting in serious loss of life. Full particulars later."

J. Bruce Ismay, Director of the White Star Line upon arriving in New York, survived by leaving the ship, without order, in a lifeboat for women and children. 705 survived; 1,523 men and (mostly poorer) women and children died with the ship, including the captain. Ismay, 50 years old at the time, died much later at the age of 74.

"From the very day that she was designed, she was almost doomed."

Louden-Brown, maritime historian, author "The White Star Line"
Titanic: How it really sank, National Geographic, 16 Mar 2012

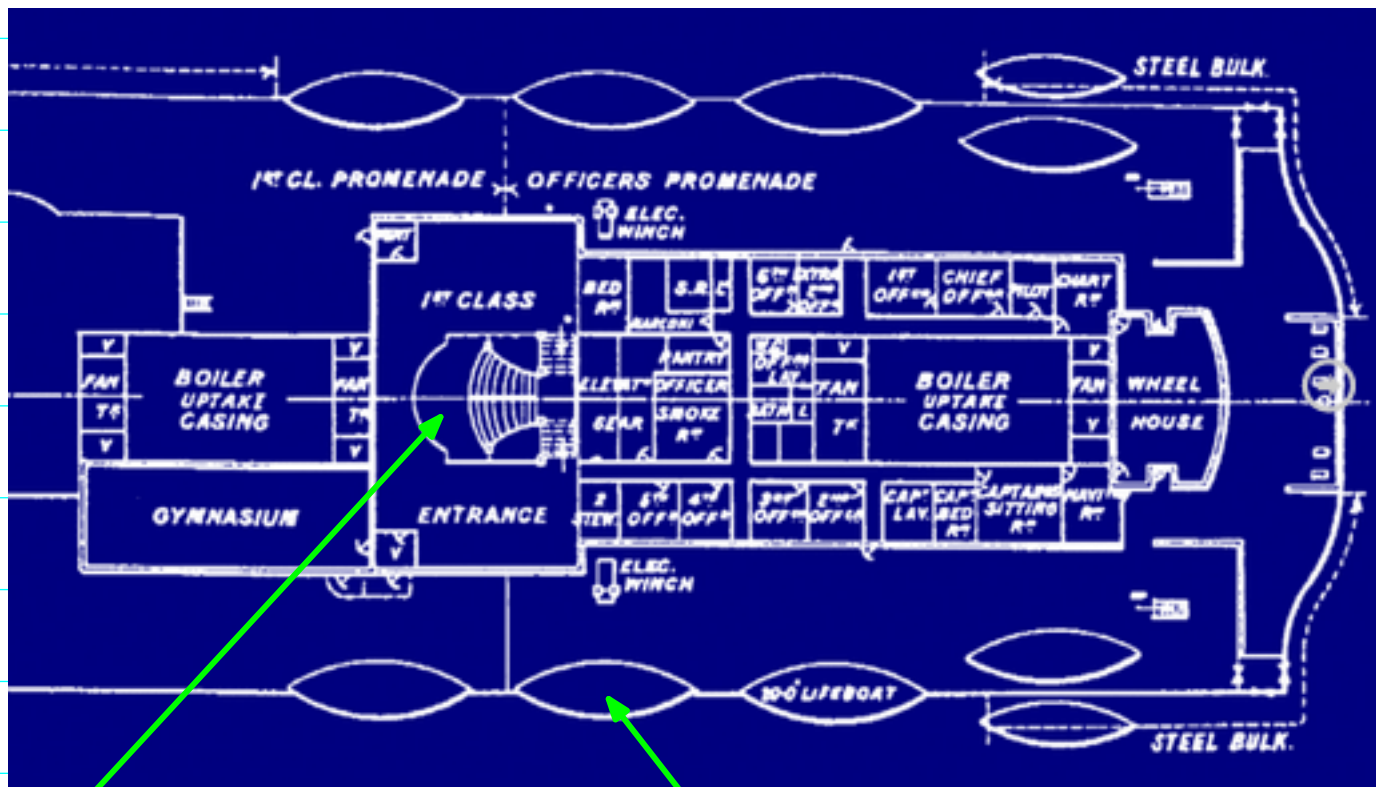
<http://www.youtube.com/watch?v=HyLjw0GAQoY>

Unfortunate engineering and safety decisions

Bulkheads were lowered, just 10 feet above waterline, to allow for the grand staircases to be grander.

Bulkheads are to create watertight compartments (cells) in the ship hull. The higher the bulkheads, the safer the ship, since water can be contained in any damaged compartment.

Boat deck plan (partial)



Grand staircase,
1st class entrance

8 of 16 large lifeboats
on boat deck



Grand staircase,
1st class entrance

<http://www.fanpop.com/clubs/titanic-2012/images/29837484/title/grand-staircase-reconstructed-photo>

Used only 16 lifeboats, instead of 48 lifeboats, to unclutter the boat deck and instill confidence in passengers.

But Titanic could have lasted longer if it did not go at full speed when collided with the iceberg... and many more other IFs...

"There must be have been a chain of unforeseen events that led to the catastrophe. A disaster of this scale never results from a single cause. That's kind of an old-fashioned way of looking at things... Instead there are a number of causes that have to come together at just the right time and at the right place."

Brian Penover, Commander, US Coast Guard
Seconds From Disaster - Sinking Of The Titanic (2006), National Geographic

Two structural failure theories

Each has a different role in the disaster.

Fractured steel hull theory

The Royal Mail Ship Titanic: Did a Metallurgical Failure Cause a Night to Remember?

Felkins, Leighly, Jankovic (FLJ) 1998, JOM, Vol.50, No.1, pp.12-18.

<http://www.tms.org/pubs/journals/jom/9801/felkins-9801.html>

Fractured wrought-iron rivet theory

Foecke 1998, Metallurgy of the RMS Titanic, NIST-IR 6118.

http://www.nist.gov/manuscript-publication-search.cfm?pub_id=852863

Charpy impact tests

Charpy test machine



Notched specimen



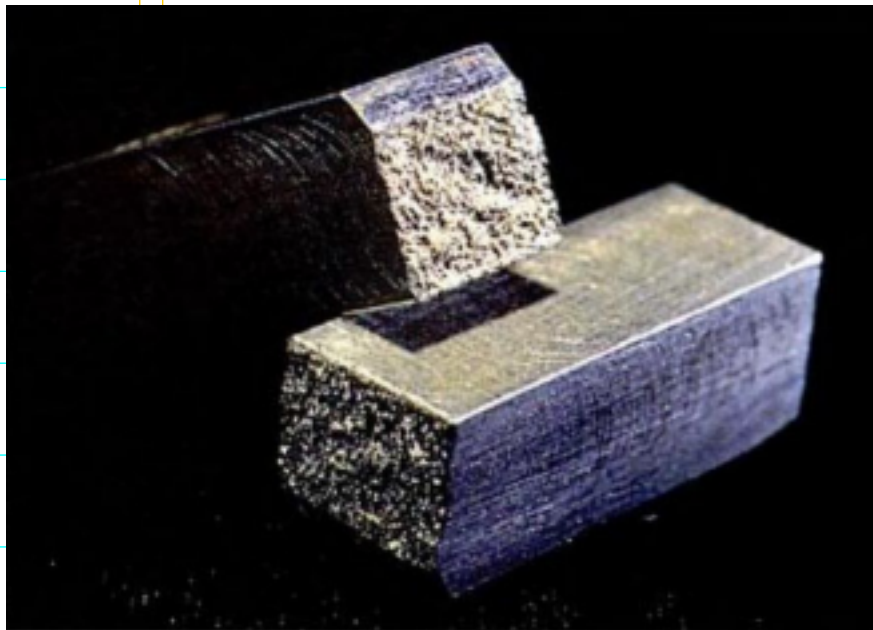
Charpy Impact Testing
Westmoreland Mechanical Testing & Research, Inc.



http://www.wmtr.com/Content/impact_testing.htm

<http://www.boulder.nist.gov/div853/Charpy.htm>

Brittle fracture Titanic steel

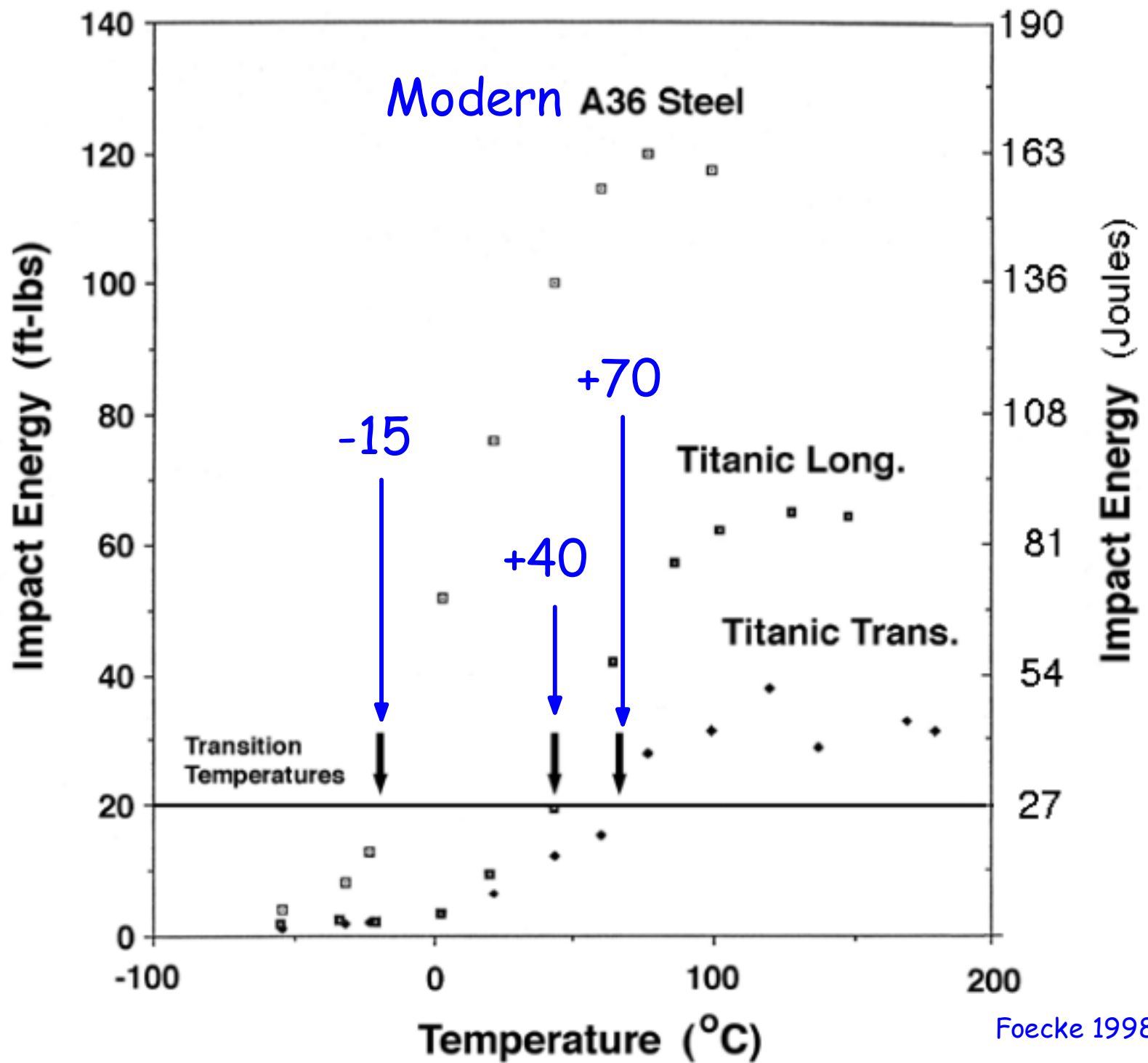


Ductile fracture Modern A36 steel



<https://bsclarified.files.wordpress.com/2012/04/titanic-fractured-hull.jpg>

Brittle / Ductile Transition Curves



Foelke 1998, Fig.2

Water temperature = -2 deg C at time of collision



Hot-rolled
steel plates

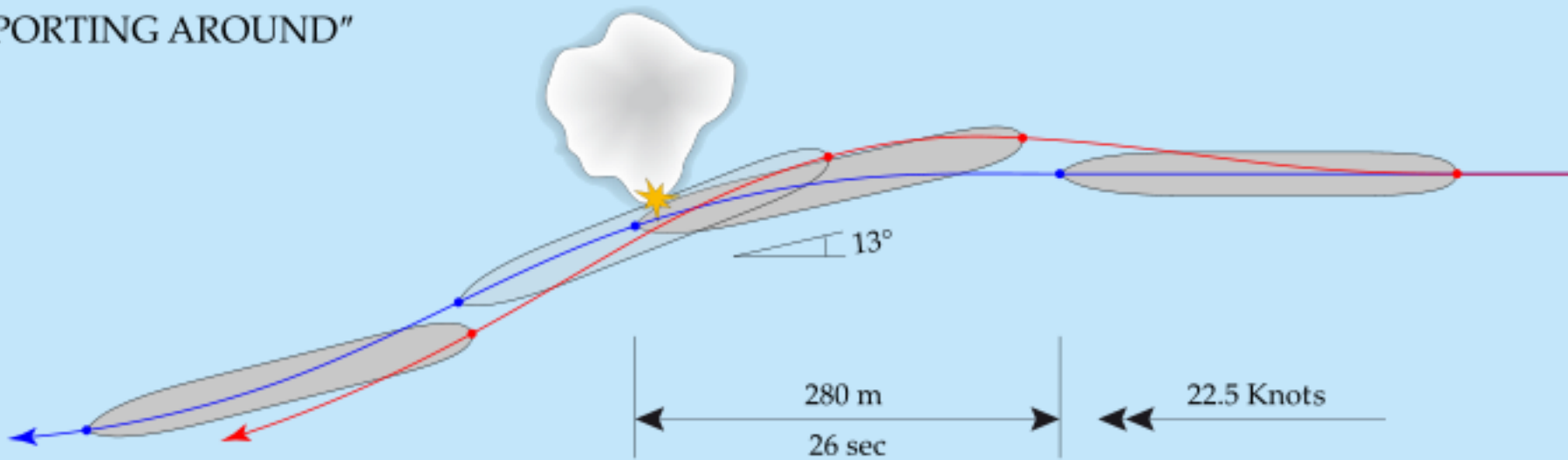
http://www.ehow.com/how_8144004_hot-rolled-steel-made.html



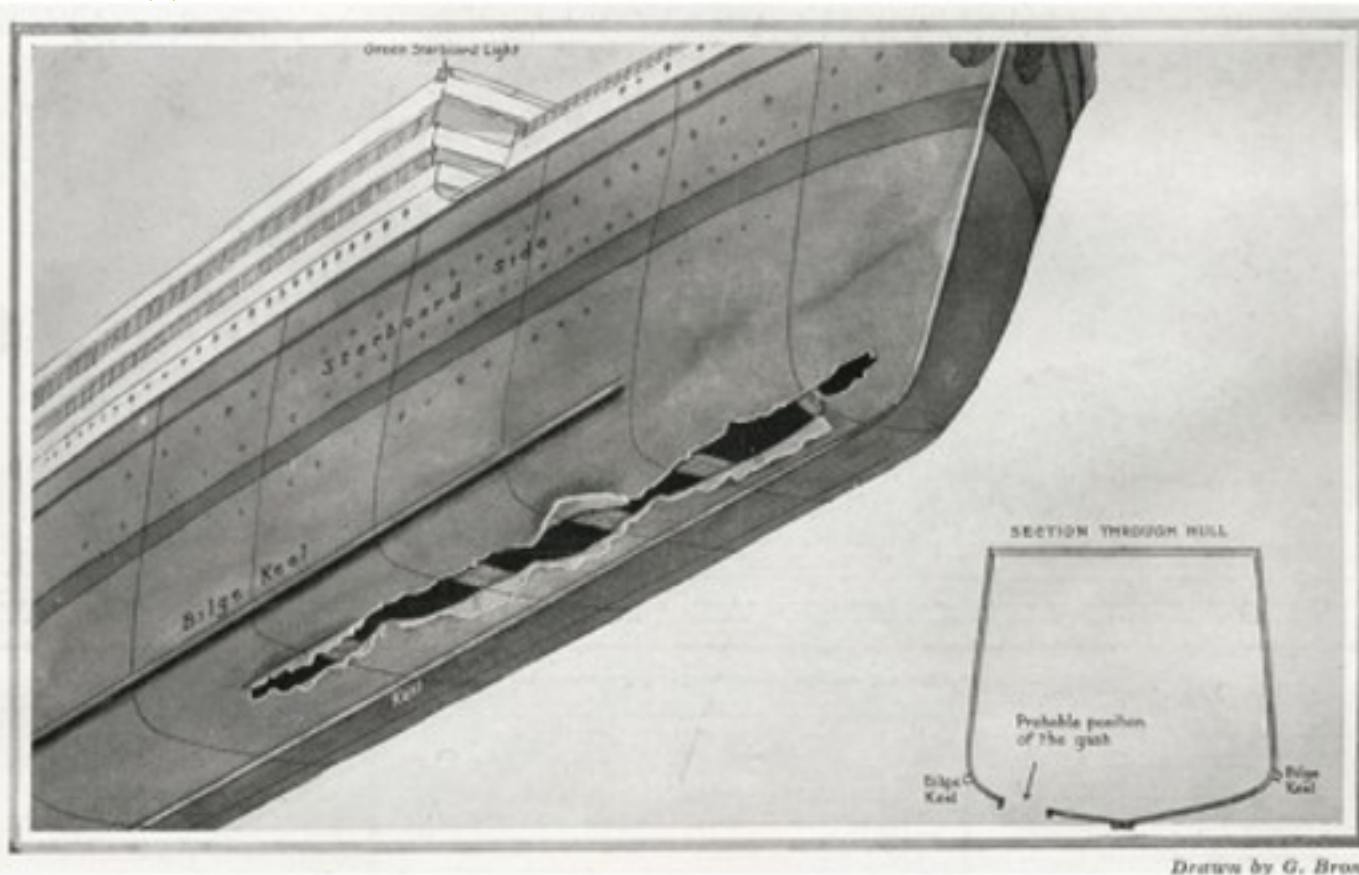
<http://cold-rolled-steel-properties.rolledsteels.com/hot-rolled-steel-plate/>

Titanic veered to portside, glancing blow with iceberg on starboard side, veered to starboard side to protect its propellers from iceberg

"PORTING AROUND"



http://en.wikipedia.org/wiki/File:Titanic_porting_around_English.svg



http://www.allposters.com/-sp/Titanic-Hitting-Iceberg-Posters_i8727278_.htm

Titanic's bow 90-meter (300-ft) gash by iceberg collision, spreading over 6 compartments, as widely believed since the British inquiry in 1912.

Titanic forward section on ocean floor, side view

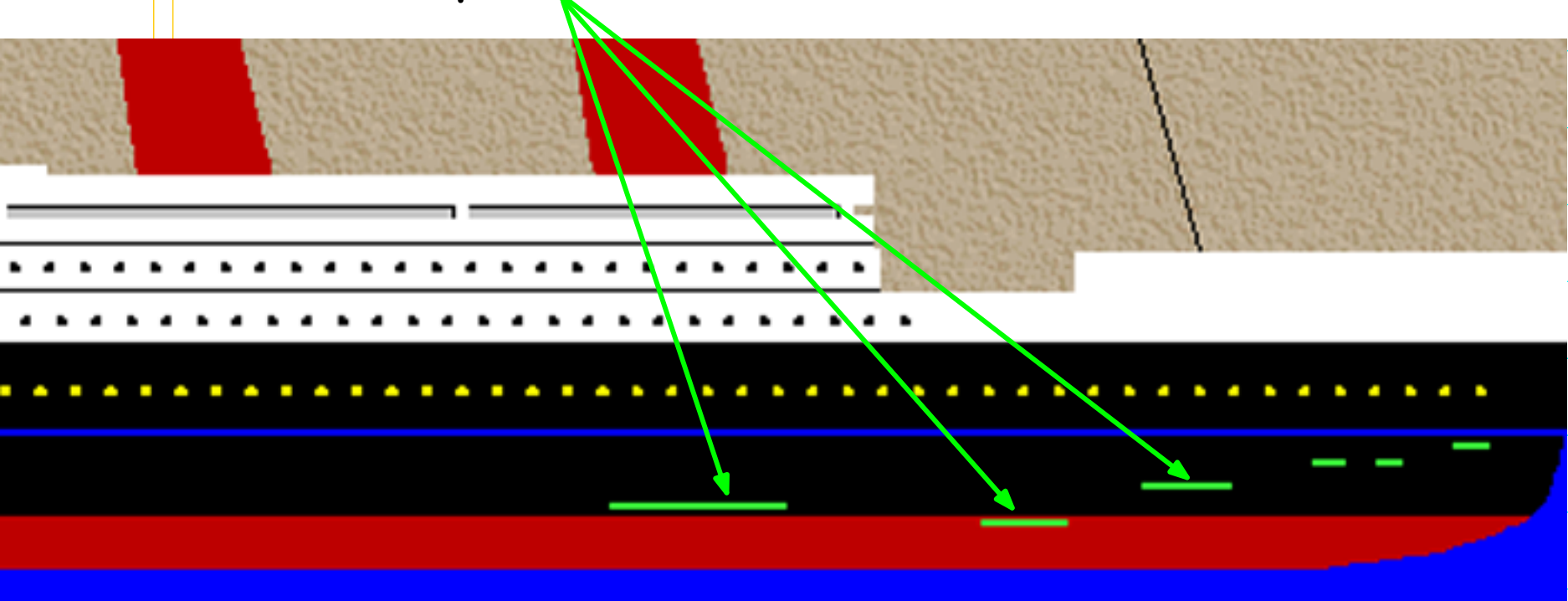


<http://photovide.com/titanic/>

Collision site under 55 ft of mud

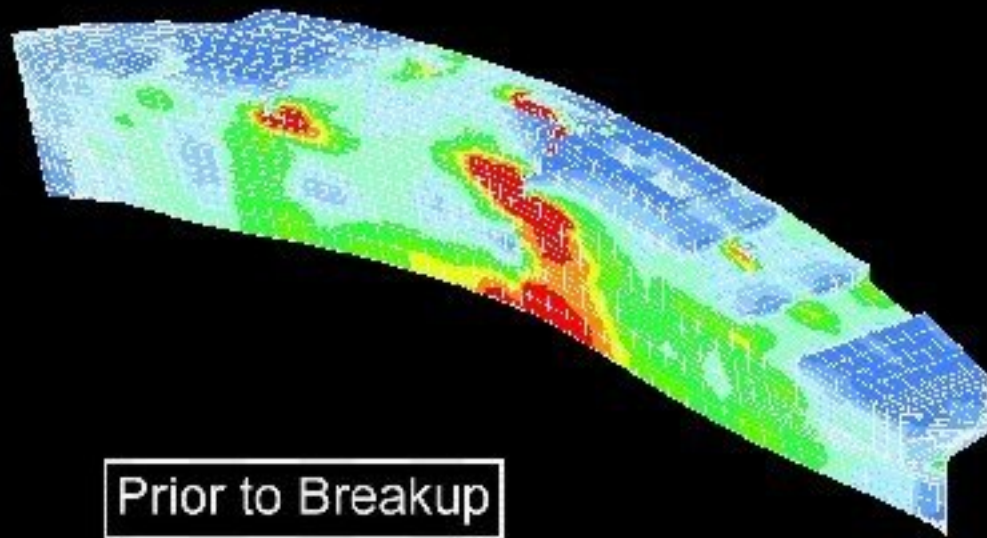
1997 French expedition

- Ultrasound imaging
- No 90-meter (300-ft) gash
- 6 narrow slits, with width of a finger, totalling about 12 square feet



Titanic broke up in half at the surface

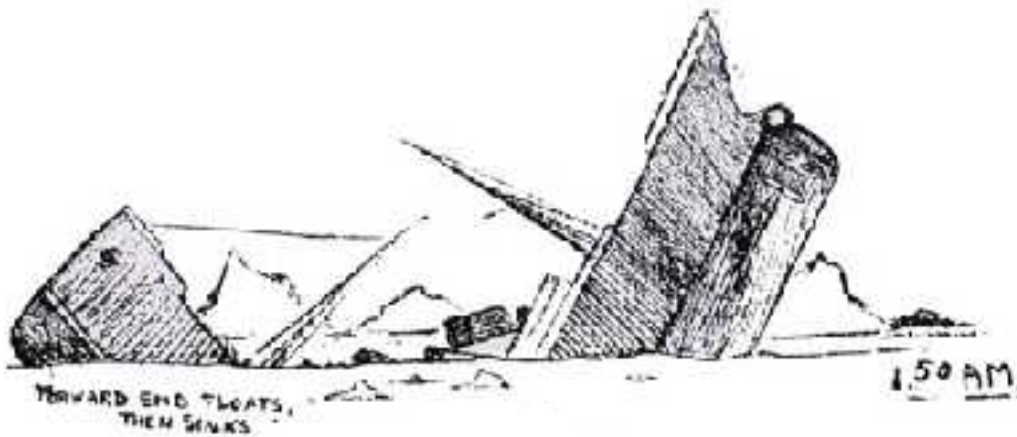
Finite Element Analysis



High Stress

Low Stress

<http://www.titanicscience.com/TitanicScience2b.htm>



Drawing by a survivor

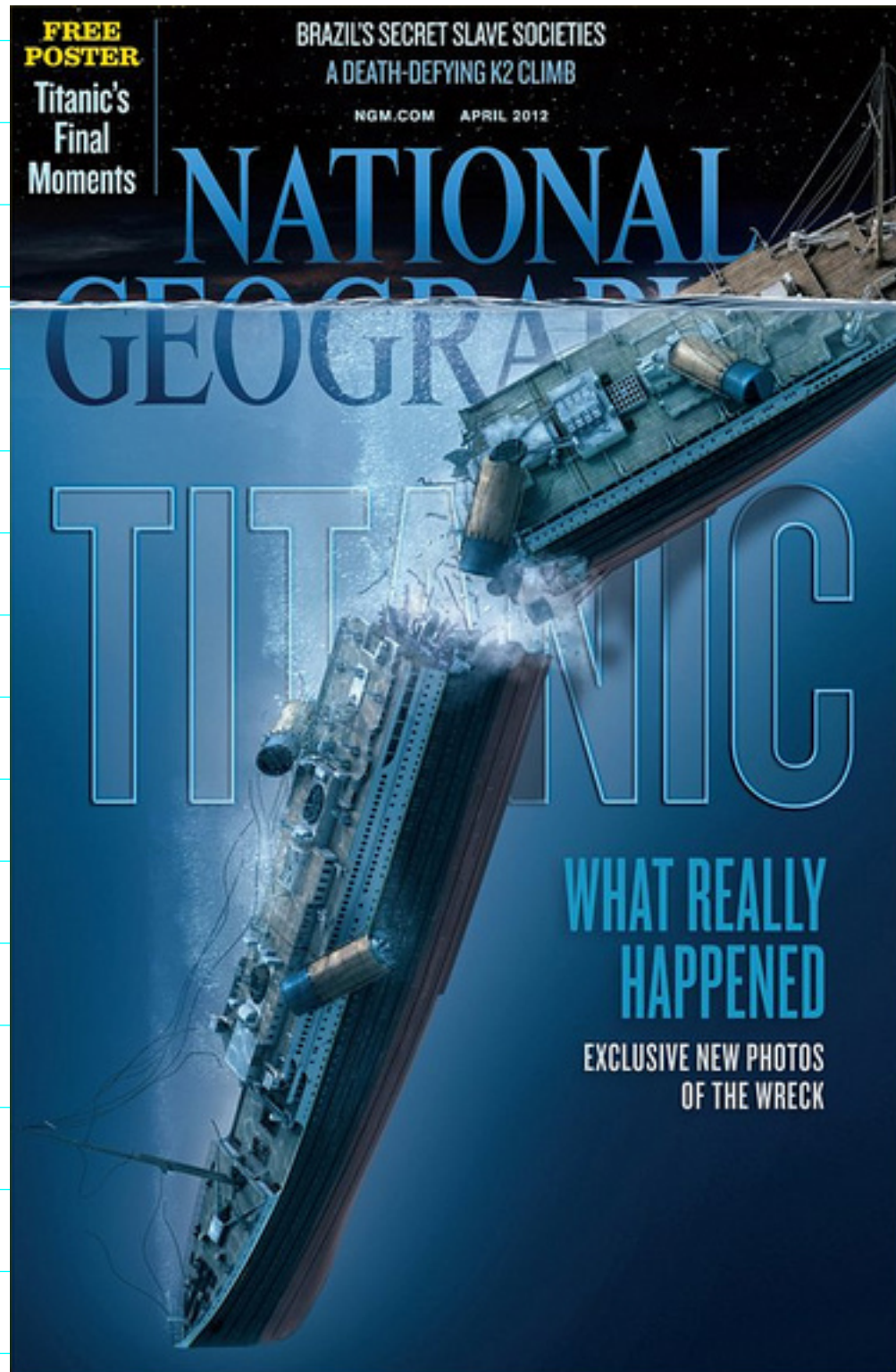
<http://www.ww2f.com/living-history/46133-how-titanic-tore-apart-3-d-imaging.html>

Artistic rendering



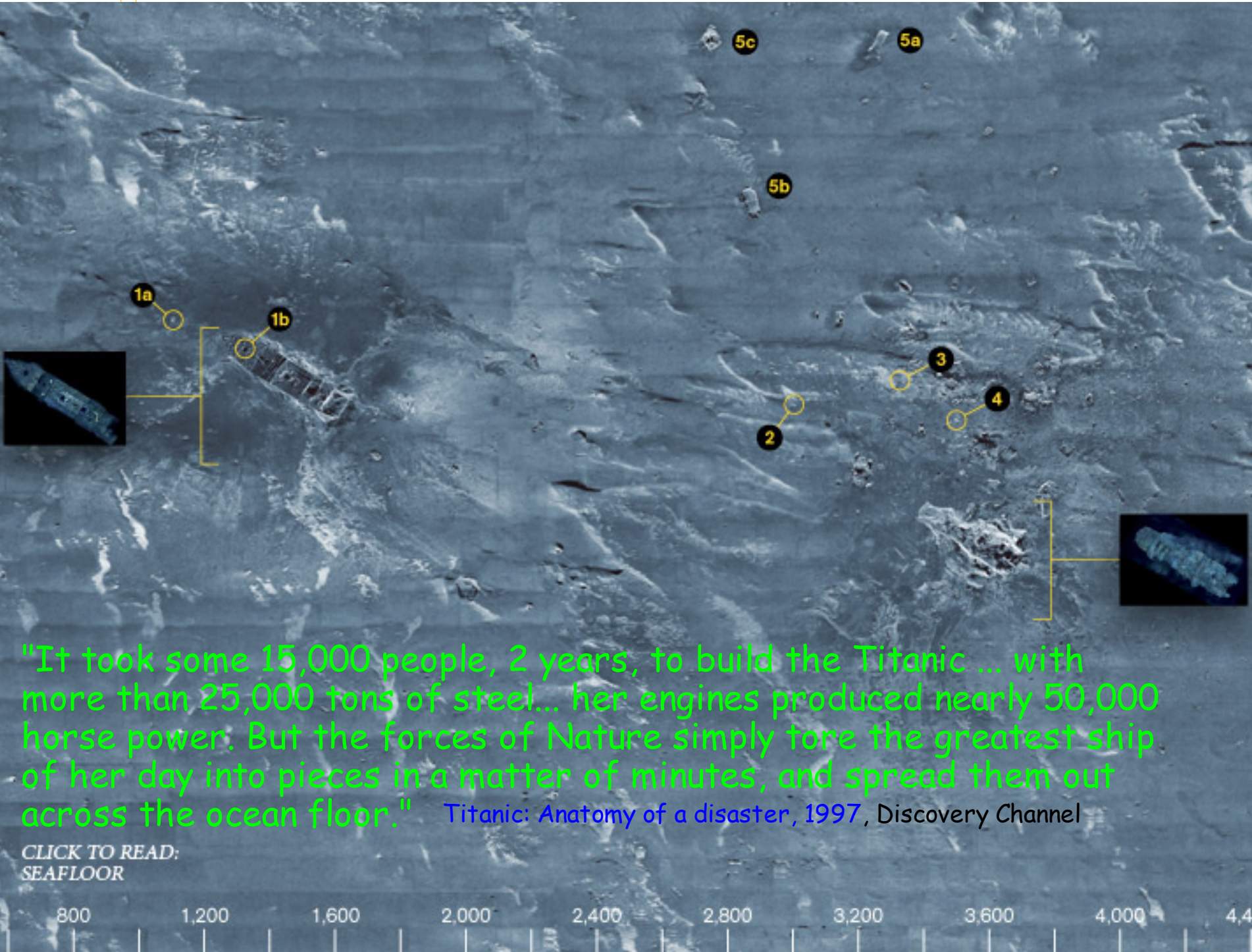
<http://modellistinavali.forumattivo.com/t1150-il-break-up-dell-rms-titanic>

Titanic broke up in half at the surface



<http://blog.hmns.org/2012/03/why-james-delgado-james-cameron-see-a-real-underwater-explorer-speak-april-12/>

Titanic debris field: Patched sonar image

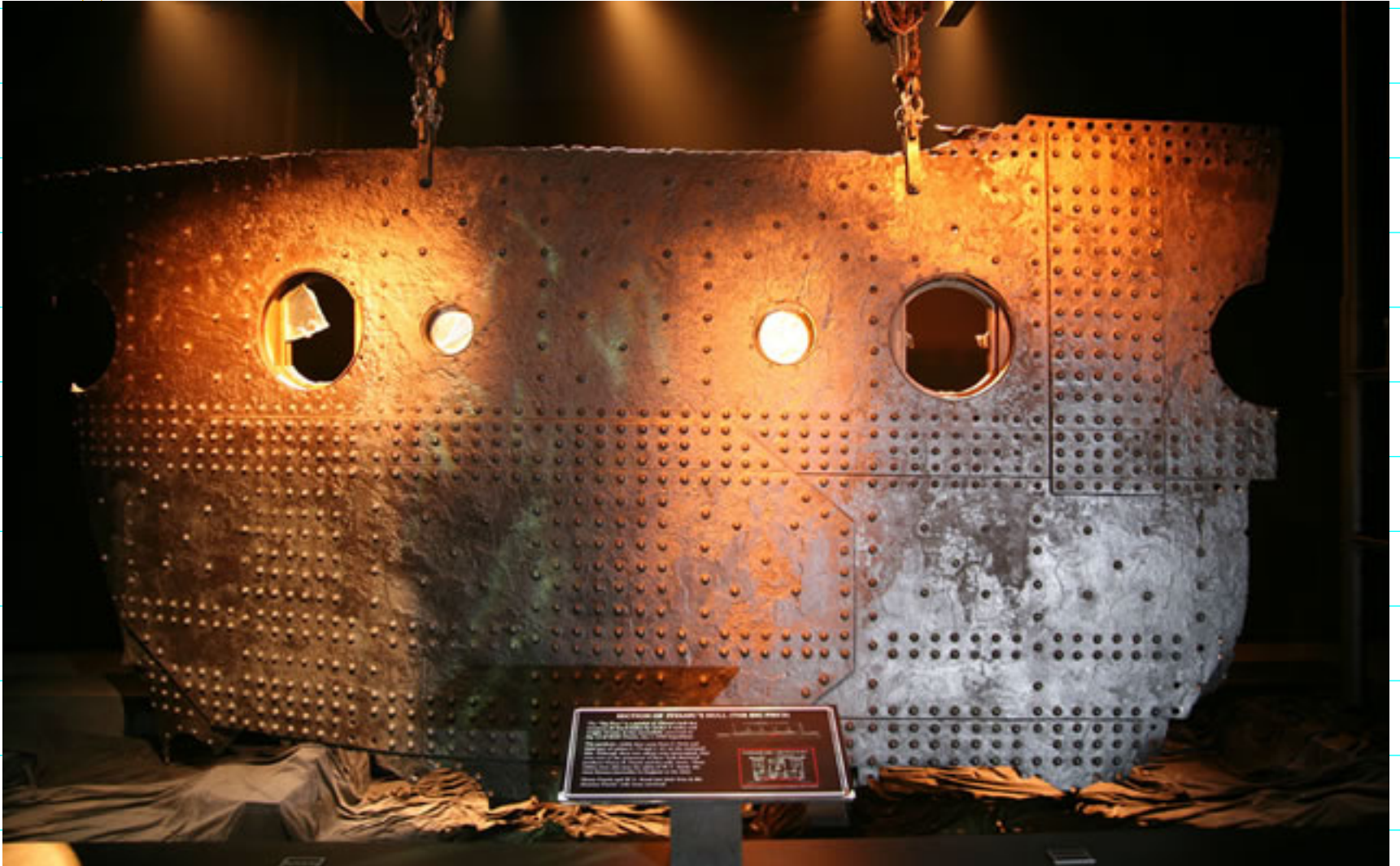


"It took some 15,000 people, 2 years, to build the Titanic ... with more than 25,000 tons of steel... her engines produced nearly 50,000 horse power. But the forces of Nature simply tore the greatest ship of her day into pieces in a matter of minutes, and spread them out across the ocean floor." Titanic: Anatomy of a disaster, 1997, Discovery Channel

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SEAFLOOR

Titanic had 2000 steel plates, each 1 in thick, held together by 3 millions steel and wrought-iron rivets.

Recovered broken steel hull

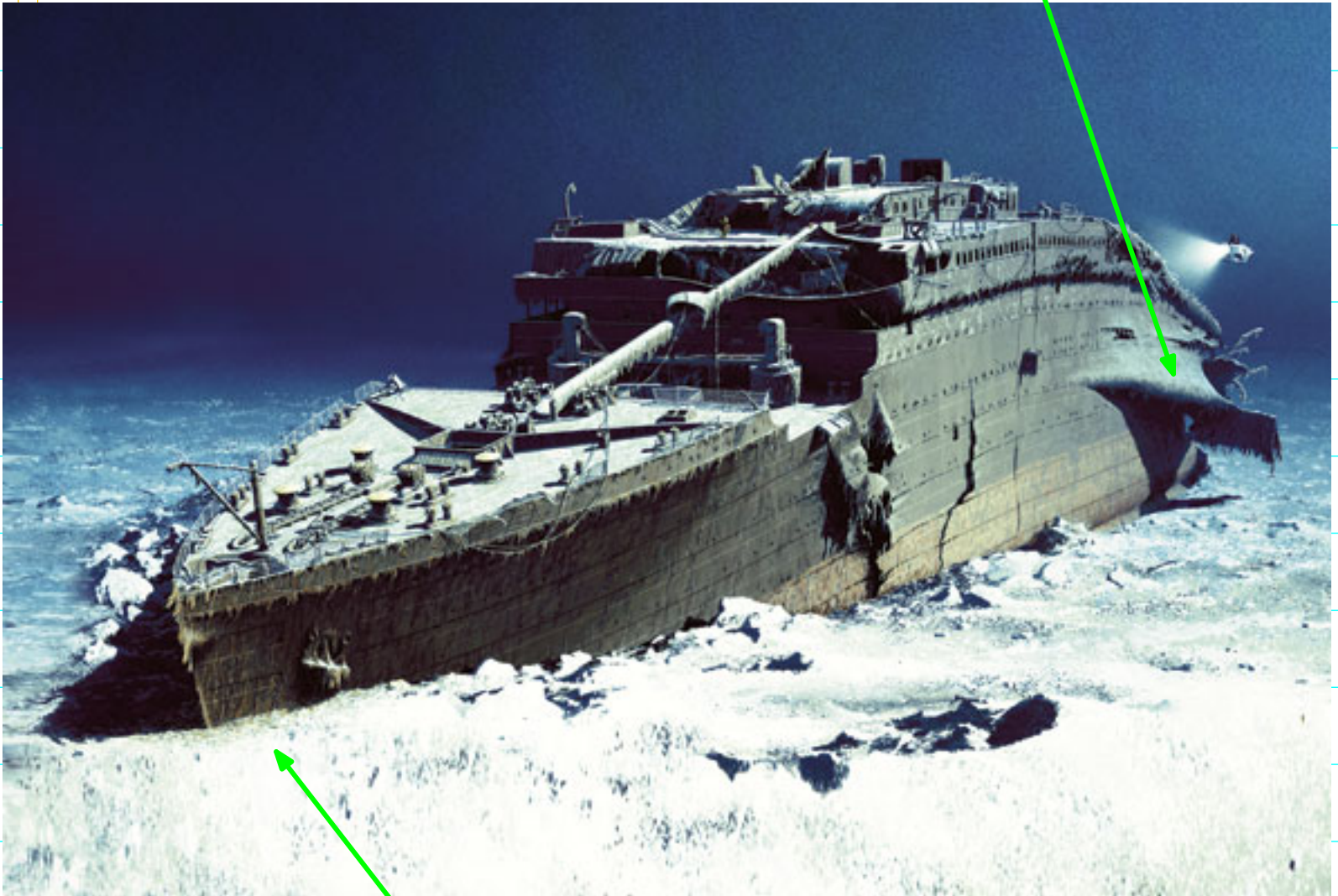


<http://tommytoy.typepad.com/tommy-toy-pbt-consultin/boats-and-yachts/>



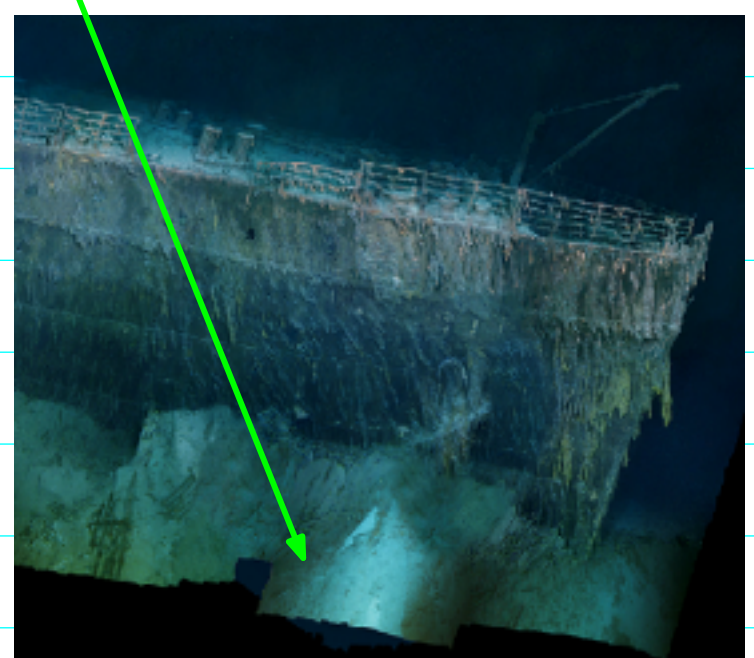
http://www.nytimes.com/slideshow/2008/04/14/science/041308Titanic_9.html

Titanic-hull steel could take on large plastic deformation with no brittle fractures like glass



<http://www.scholastic.com/browse/article.jsp?id=3757130>

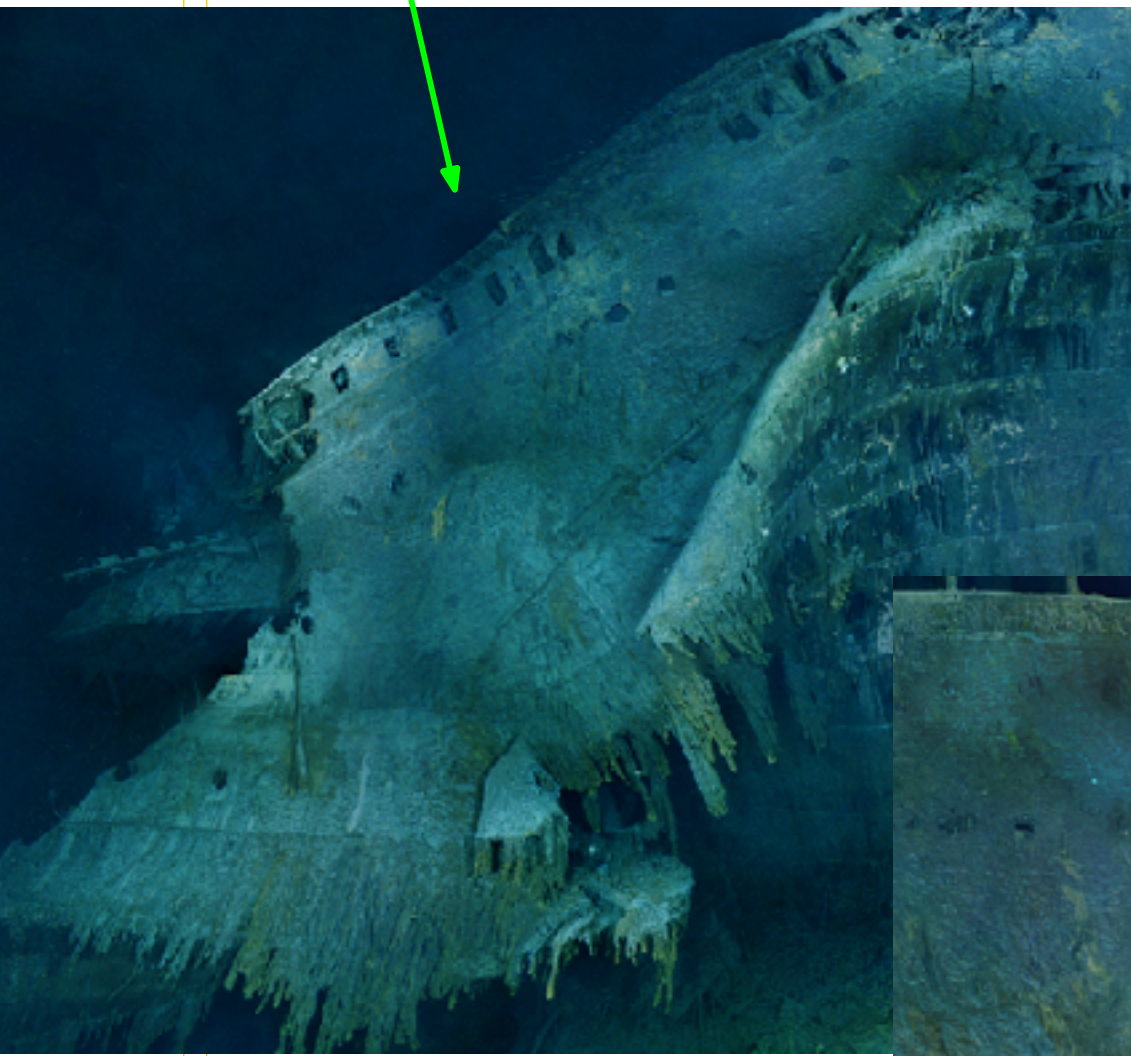
Bow bottom under 55 feet of mud



<http://good-report.com/4393/amazing-new-images-of-titanic-wreck-revealed>

<http://ngm.nationalgeographic.com/2012/04/titanic/starboard-bow-interactive>

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Titanic-hull steel could take on large plastic deformation before breaking; no brittle fractures

RMS Olympic, sister ship of RMS Titanic, collided with HMS Hawke in 1911: Damage

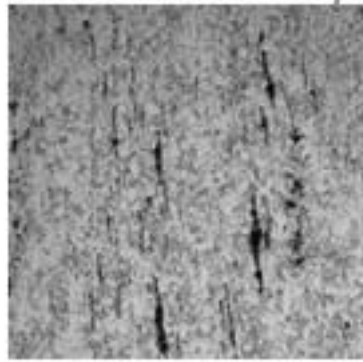
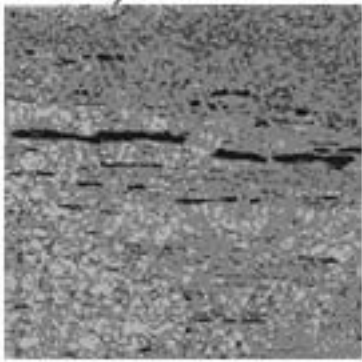


→ **Plastic deformation** in steel hull-plates:
Bending and twisting

→ **Missing rivets**

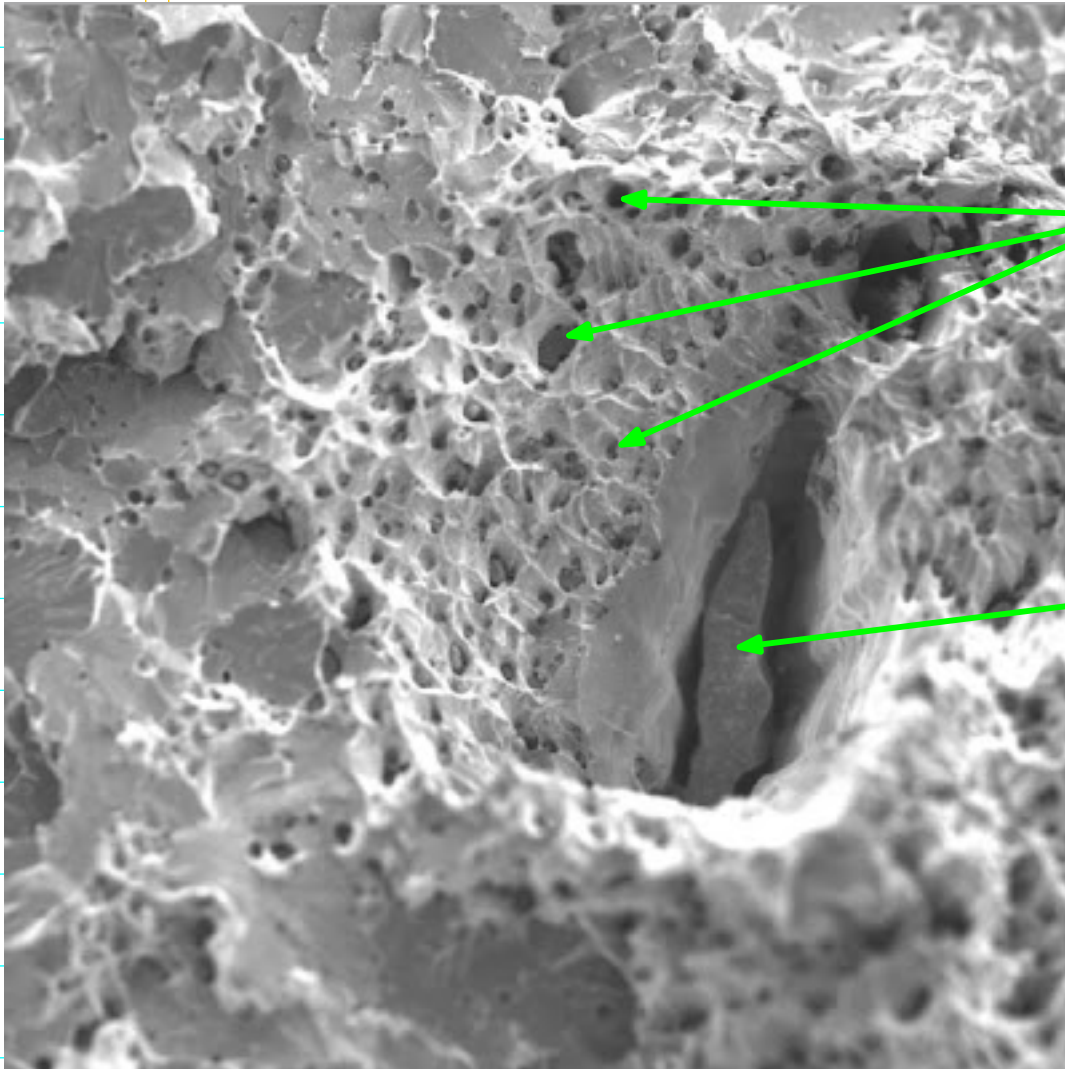


Titanic rivet with a lost head (right)



Slag is made of silicon (rock, sand, glass)

http://www.cite-sciences.fr/english/ala_cite/expo/tempo/titanic/science/zoom-rivet.html



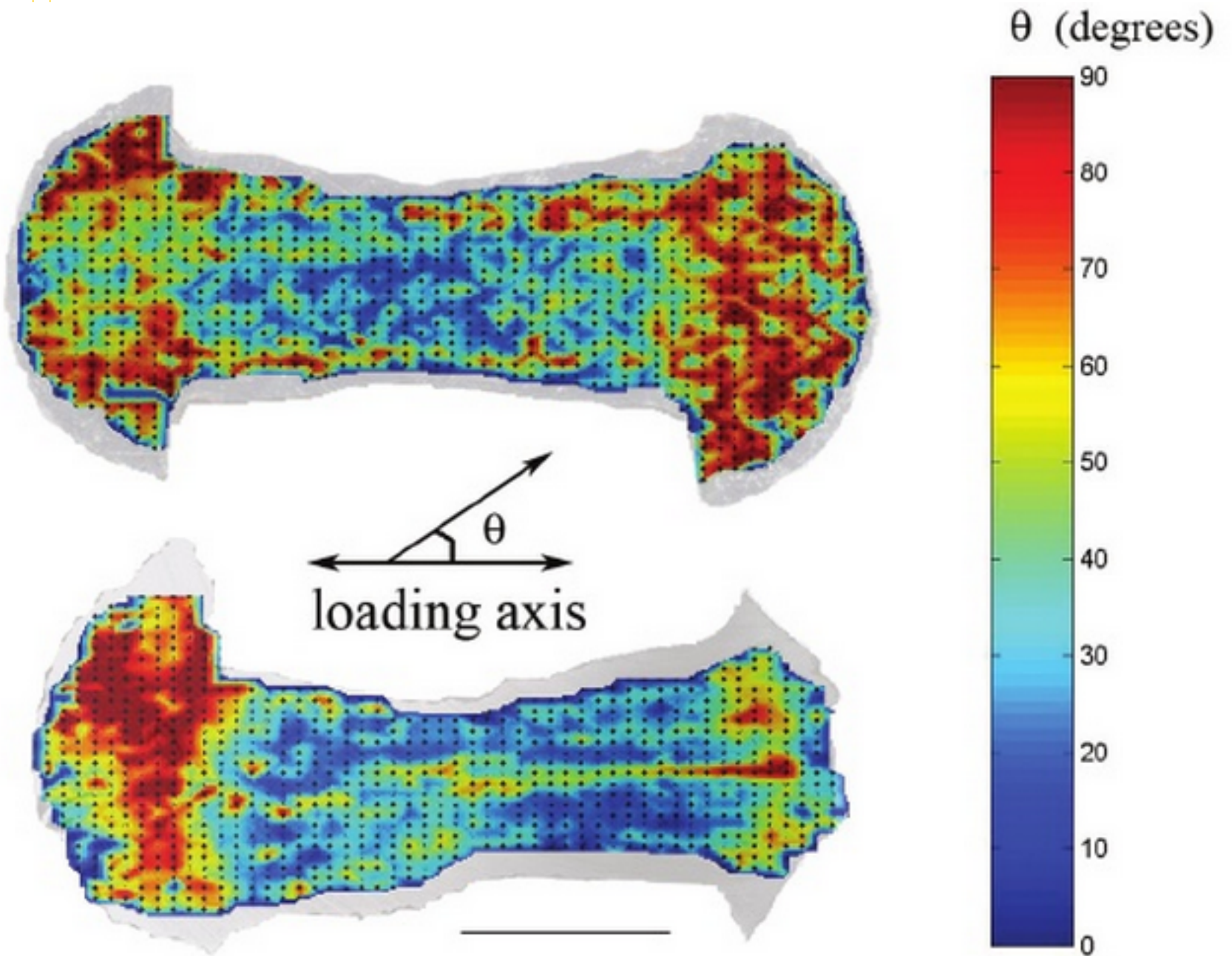
Slag particles

Slag stringer, perpendicular to horizontal rivet axis

No interfacial bonding

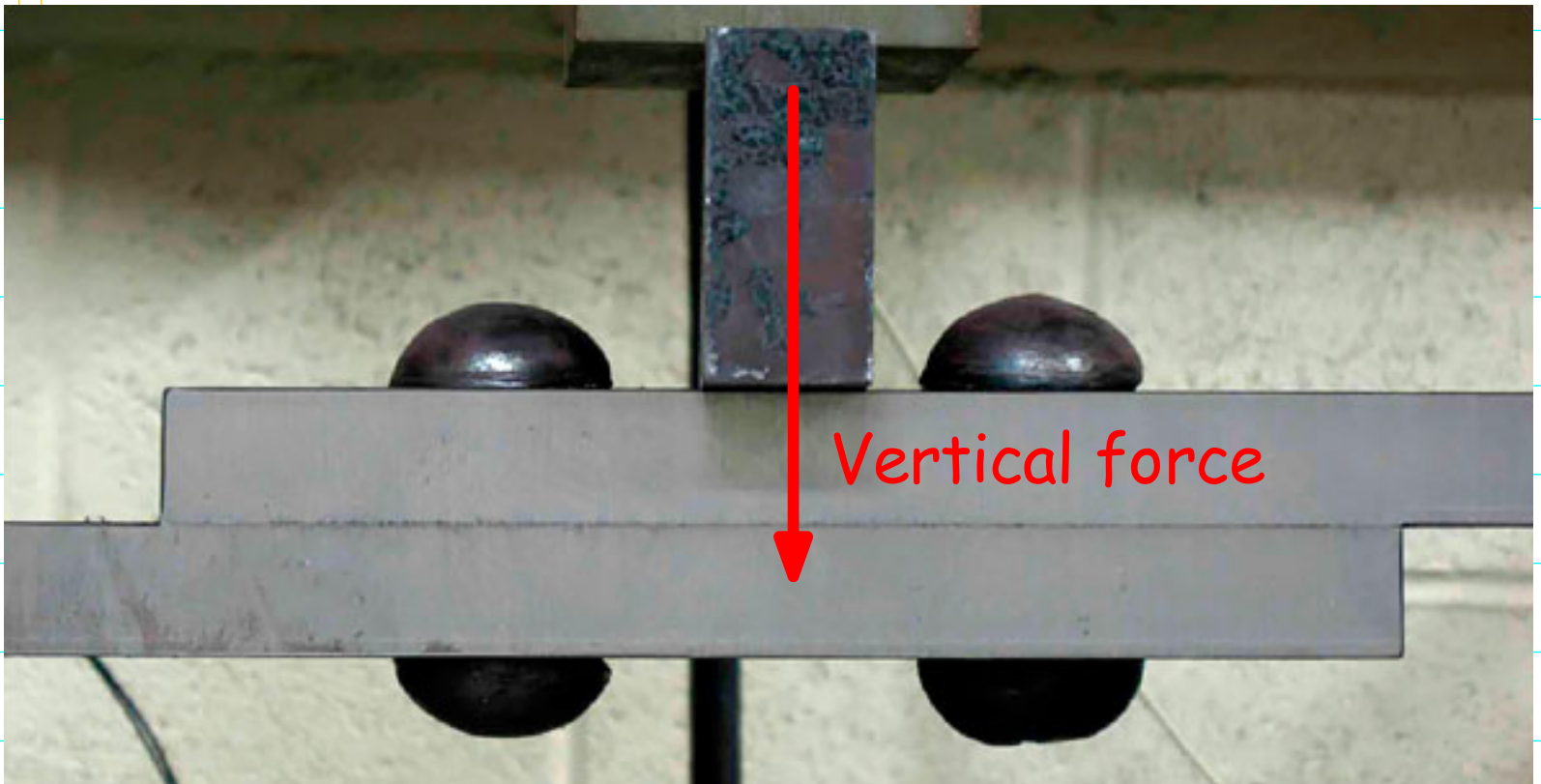
<http://idea-power.blogspot.com/2008/05/root-cause-analysis-part-2.html>

Titanic rivets: Slag stringer orientation



Slag stringers in rivet heads are oriented 90 deg (perpendicular) to rivet shaft axis; weakness against tension, leading to loss of rivet heads and opening of 6 slits in the seams of the ship hull.

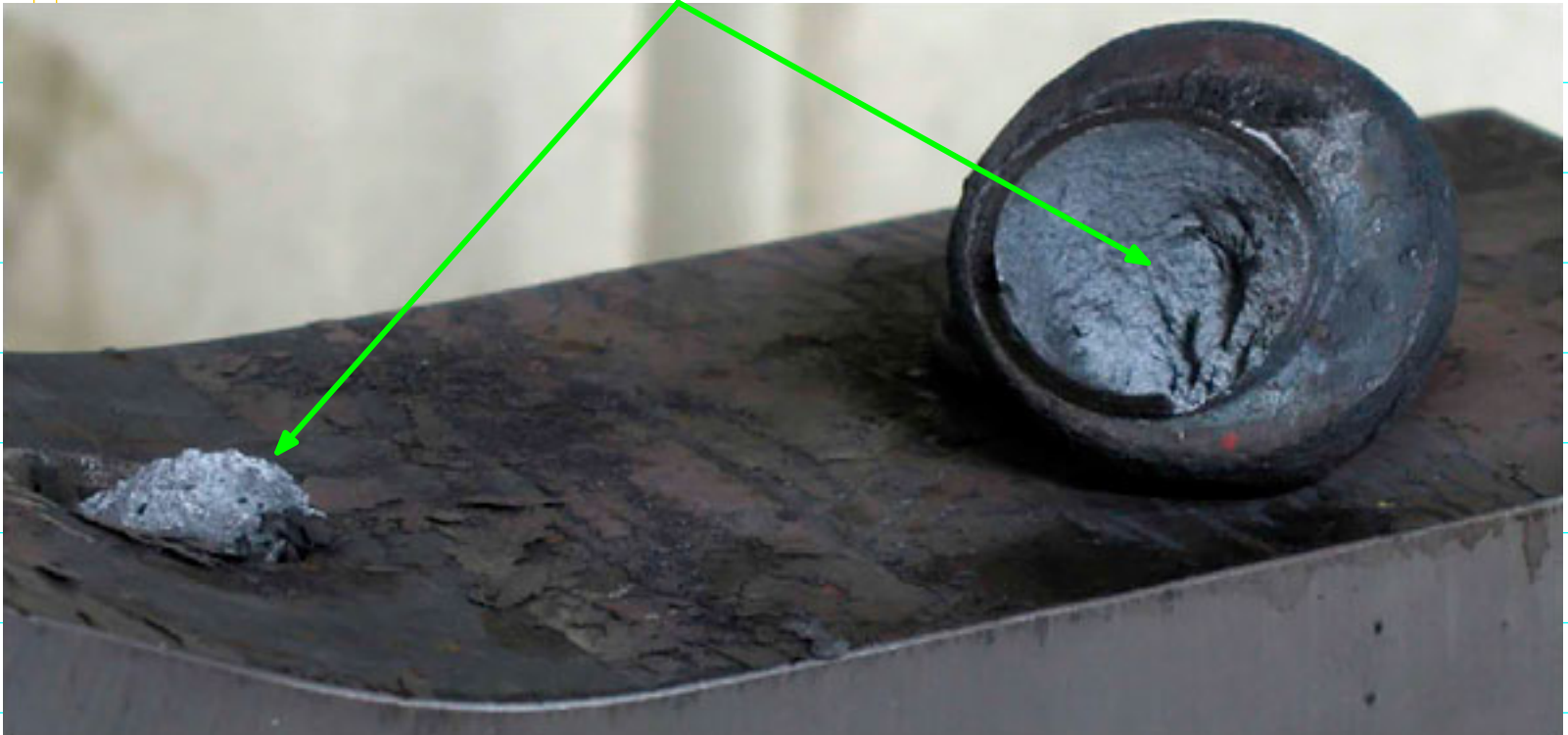
Testing rivets made identical to those of the Titanic



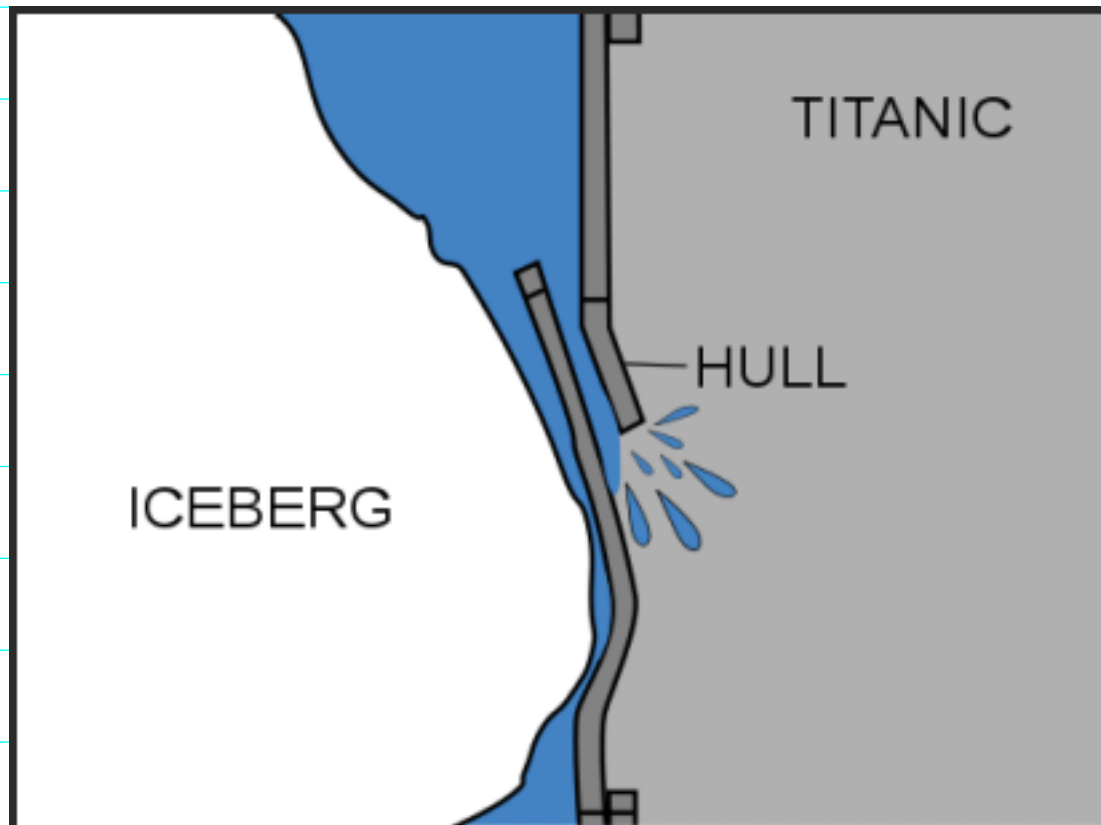
Rivet head popped off at 60% of ultimate force on good rivets



Small button inside rivet head similar to those recovered from the Titanic site (p.51-13)



http://www.nytimes.com/slideshow/2008/04/14/science/041308Titanic_11.html



[http://en.wikipedia.org/wiki/File:Iceberg_and_titanic_\(en\).svg](http://en.wikipedia.org/wiki/File:Iceberg_and_titanic_(en).svg)

Safety lesson

Empty Titanic lifeboats in New York



<http://cruiselinehistory.com/rms-titanic-wreck-of-the-titan-and-the-lifeboats/>

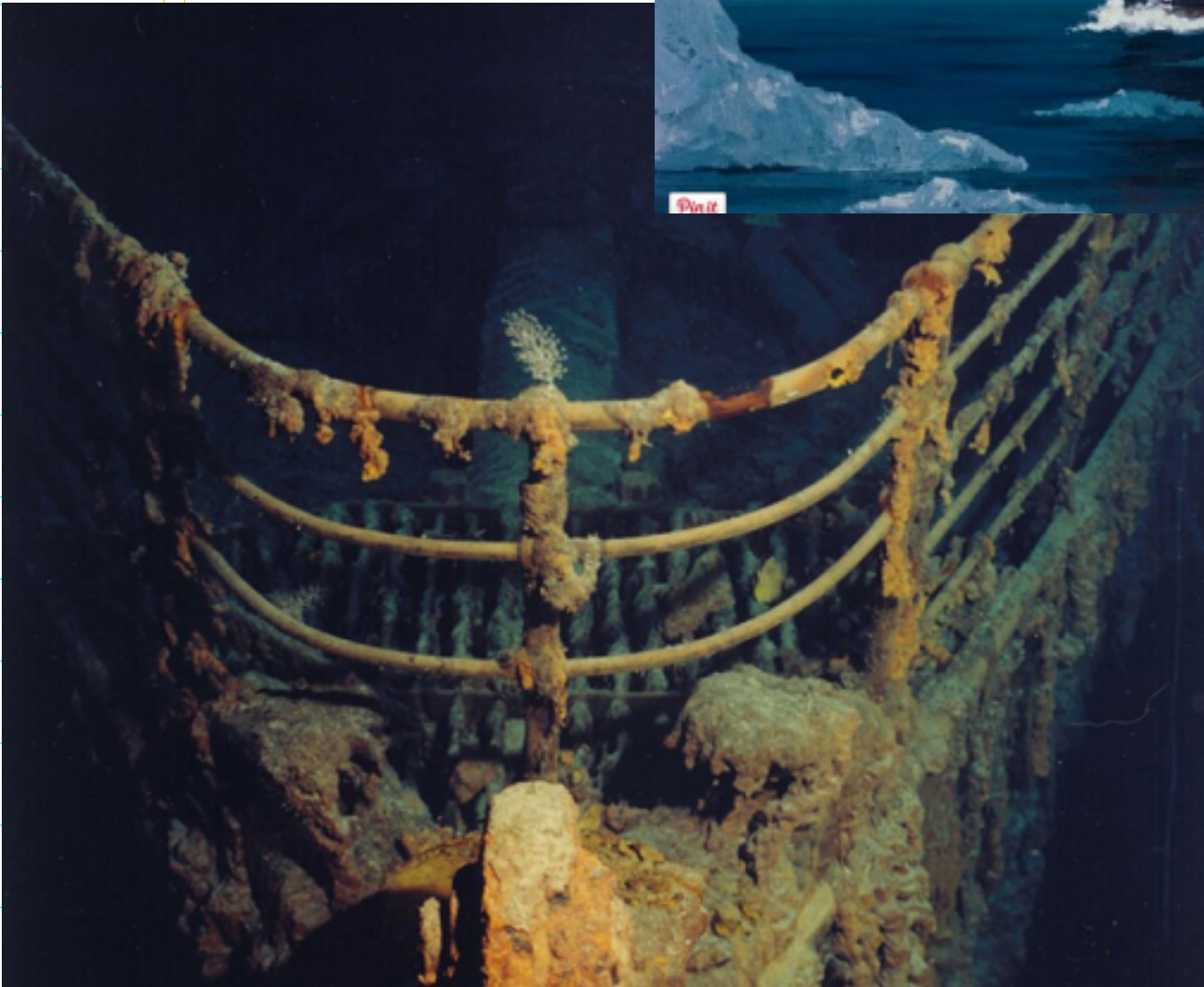
"The Titanic represented a time of great optimism. It was believed that technology reigned supreme over Nature. When the great ship set sail, no one was concerned about not enough lifeboats were onboard. But after this incredible disaster, safety philosophy would change forever. Today, we know unsinkable ships cannot be built. Designs now focus on keeping vessels afloat just long enough to be abandoned."

Titanic: Anatomy of a disaster, 1997, Discovery Channel

<http://www.youtube.com/watch?v=ZLWRa-ym-L8>

"everything recycles, absolutely everything ... the most luxurious ocean liner in the world is slowly disintegrating, transforming into dust and iron ores."

Titanic: Anatomy of a disaster, 1997, Discovery Channel





A 1898 novel about the sinking of a largest ever-made ship called the Titan, 14 years before the sinking of the Titanic.

"She was the largest craft afloat, the greatest of the works of man. A floating city, she carried only as many lifeboats as would satisfy the law. Unfortunately, she hit an iceberg, the only thing afloat she could not conquer, and thousands were plunged into the icy North Atlantic, their voices raised in agonized screams."