Behind Disasters: A Layman's Impressions

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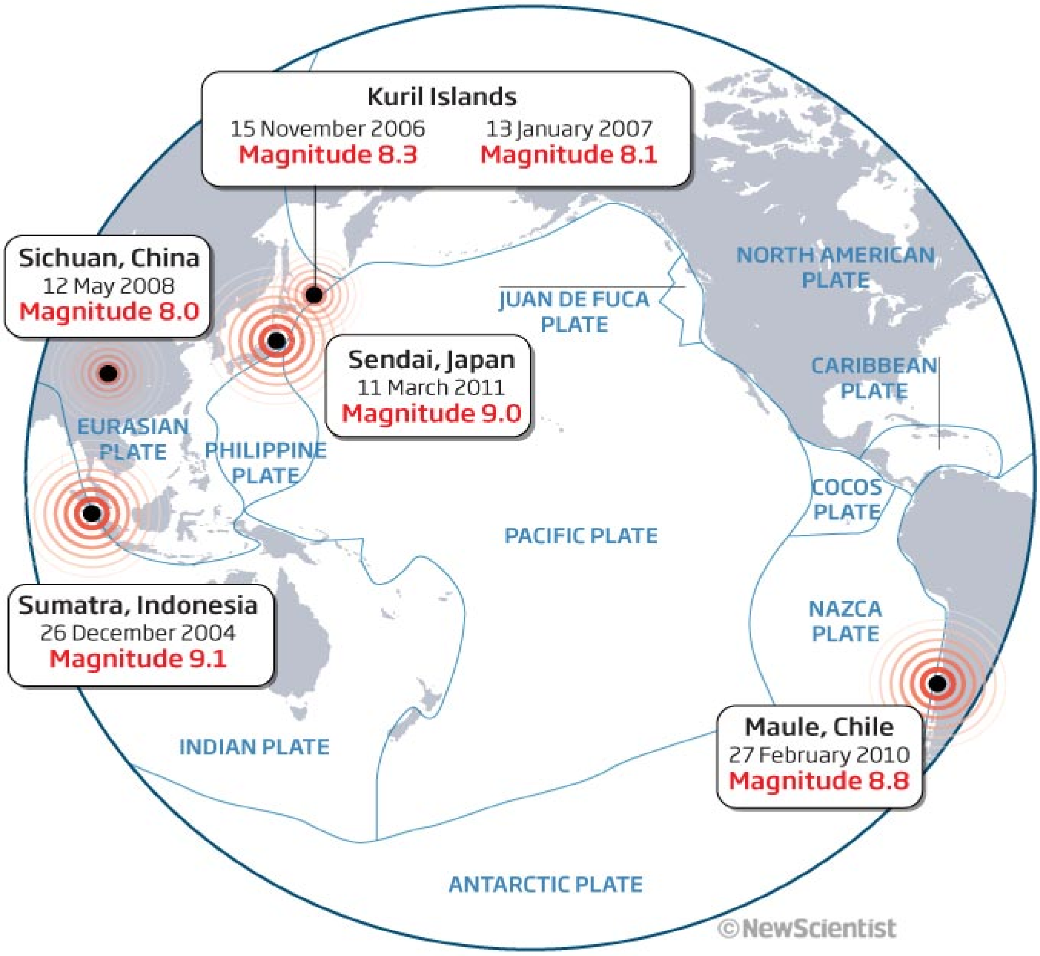
There have had been so many disasters which demonstrate to us human fragility and Mother Nature's own rule. The recent Japanese earthquake and tsunami, plus the nuclear crisis, serve as a sad reminder. I compile here some of the "facts", questions and controversies that we as laymen should be aware of. I am not an expert in the fields and don't have firm answers to most issues, if any at all.

1. Are huge earthquakes linked?



Source: http://www.ritholtz.com/blog/wp-content/uploads/2011/03/28043001.jpg

1-A. No

Most geologists believe that the number of super earthquakes is too small to enable a statistically convincing case for a correlation. In a recent report, Tom Parsons of the U.S. Geological Survey and Aaron Velasco of the University of Texas at El Paso looked at worldwide earthquake records for the 30 years ending in 2009. They counted 205 big earthquakes, with magnitude of 7 or more, and 25,222 moderate ones with magnitudes between 5 and 7. They concluded that "big earthquakes don't set off other dangerous ones around the globe. Big quakes do trigger local aftershocks, but researchers found no sign of setting off moderate-sized events beyond about 600 miles away."[1]

1-B. Yes

On the other hand, a minority feels that there must be a link between recent events. "What is clear is that for the 6.2 years since 2004, there have been more great earthquakes around the world than in any 6.2-year period throughout the 110-year history of seismic recordings," says Thorne Lay at the University of California, Santa Cruz. His colleague Emily Brodsky goes further: "The recent spurt of magnitude-8-plus earthquakes may be an extended aftershock sequence of the 2004 Sumatra earthquake."

Lay suggests a geological mechanism that can correlate some large quakes that take place several months apart. He cites doublets (pairs) which occurred on the same or neighbouring faults within months of each other. In November 2006, an 8.3-magnitude quake shook the Kuril Islands north of Japan as the Pacific plate pushed beneath them. Two months later, in January 2007, the islands felt the force of a second 8.1-magnitude quake.

Doublets like this do not prove a linkage of events separated by longer periods and greater distances. For this, scientists need to "show that a region which has experienced a large quake recorded unusual seismic activity and perhaps even some small tremors during a previous large event elsewhere on the planet. This might suggest that the earlier event unsettled a fault, effectively priming it."[2]

2. Types of nuclear reactors

Japan was hit by a triple whammy: earthquake, tsunami and a nuclear crisis. Many have blamed the Fukushima reactors for being outdated in construction.

Among various designs in the world, currently three major types of nuclear fission reactors dominate: (1) Boiling water reactors (BWRs), (2) Pressurized water reactors (PWRs) and (3) CANada Deuterium Uranium reactors (CANDUs). PWRs are numerically the most popular on the whole. Fukushima's six reactors are essentially BWRs.

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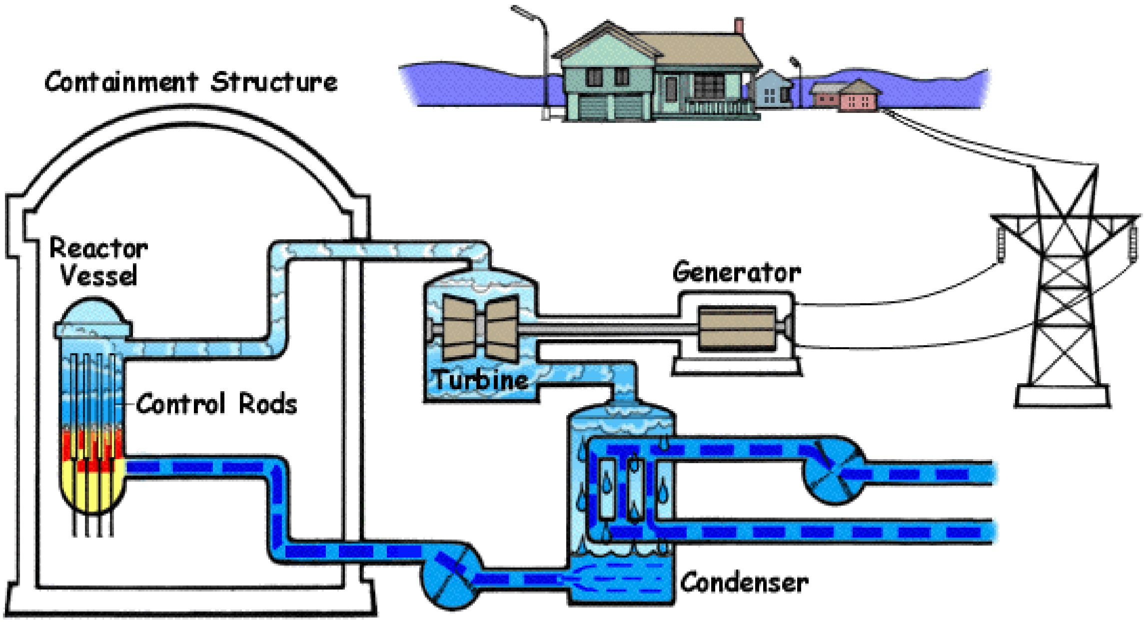
[1] Malcolm Ritter, "Big Earthquakes Study Indicates They Don't Set Off Others Far Away", 27/3/2011 (http://www.huffingtonpost.com/2011/03/27/big-earthquakes-chain-reaction_n_841226.html)

[2] Catherine Brahic, "The megaquake connection: Are huge earthquakes linked?" 16 March 2011 (http://www.newscientist.com/article/mg20928043.000-the-megaquake-connection-are-huge-earthquakes-linked.html?full=true&print=true)

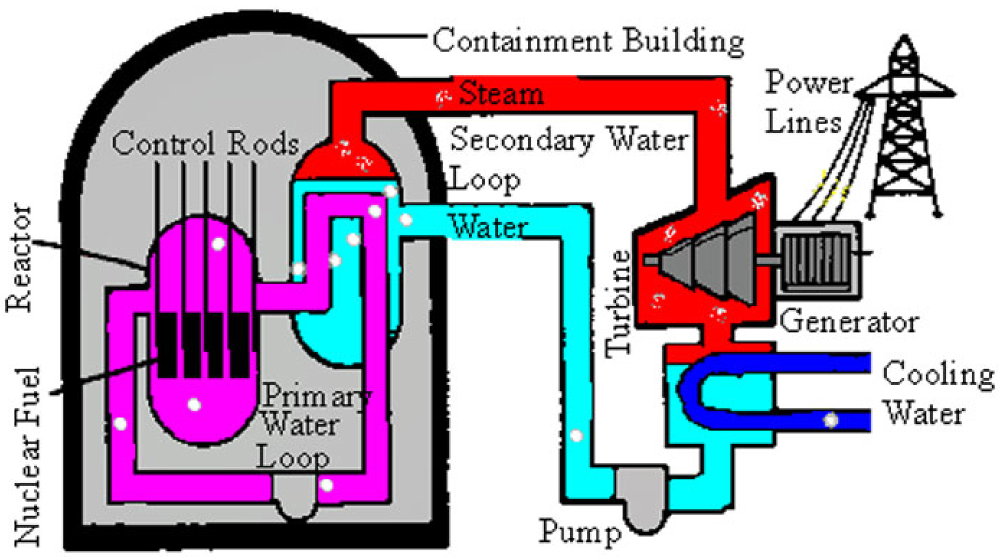
The Boiling Water Reactors (BWRs)



http://www.nrc.gov/reading-rm/basic-ref/students/animated-bwr.html

BWRs actually boil the water, which is converted to steam to drive the turbine, and then recycled back into water by a condenser, to be used again in the heat process. Radioactivity is therefore not directly sheltered outside the reactor vessel. Fukushima's six reactors belong to this type.

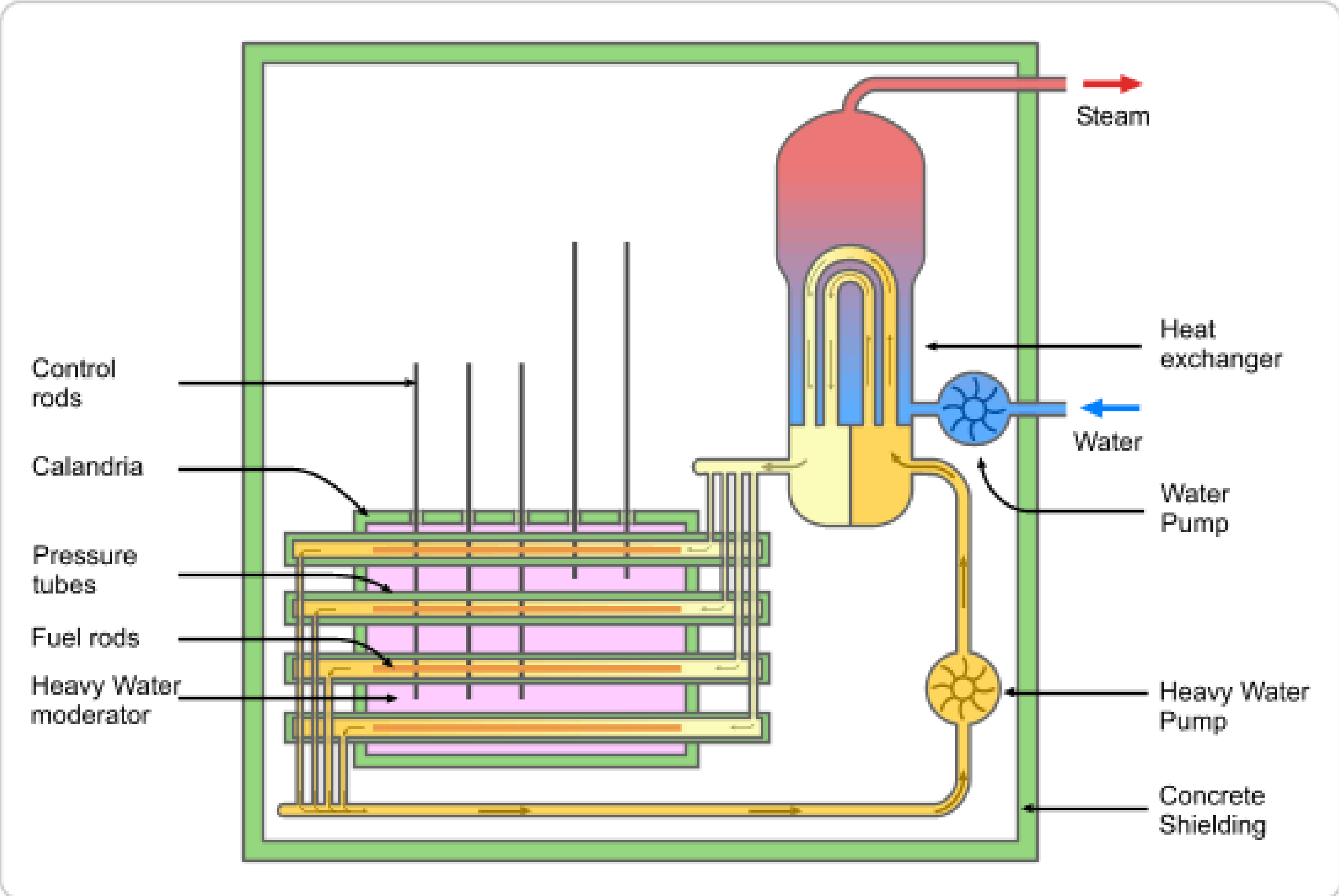
Pressurized Water Reactors (PWRs)



http://www.learner.org/courses/envsci/visual/visual.php?shortname=reactor

Pressurized-water reactors typically have two loops, instead of one as in the case of BWRs. The water in the primary loop is circulated under pressure to keep from boiling. Water from the reactor and the water in the steam generator that is turned into steam never mix. In this way, most of the radioactivity stays in the reactor area.

CANDU reactors (CANDUs)



http://www.ustudy.in/node/3169

While BWRs and PWRs use normal “light” water as coolant, CANDUs use “heavy” water. One of the unique features of a CANDU reactor is that it allows on-line fuelling. The fuel bundles are placed in horizontal pressure tubes. These tubes can be loaded remotely from either end while the reactor is still running. This avoids scheduled shutdowns for replacing some of the fuel. The CANDU design requires significantly more “plumbing” than a PWR reactor, as each pressure tube has high pressure heavy water passing through it.

CANDUs are supposedly the most efficient of all reactors in using uranium (U 鈾). They employ on average 15% less uranium than a pressurized water reactor for each megawatt of electricity produced. Use of natural (un-enriched) uranium widens the source of supply and makes fuel fabrication easier. Most countries can manufacture the relatively inexpensive fuel.

3. Safety, nuclear waste and reprocessing into weapons

A CANDU reactor is regarded as probably the safest so far. Each pressure tube is a protecting mechanism. As to BWRs and PWRs, common sense might point to the latter as superior as they have two loops instead of one. Radioactivity is not a headache if only the second loop is broken after an earthquake. However, in the case of a huge quake when both the containment building and reactor are partly destroyed with the fuel rods exposed, the consequences would almost be the same.

How lethal is nuclear waste and can it be readily transformed into weapon-grade material? The answer depends on the type of fuel used. BWRs and PWRs typically use “low enriched uranium” (plus a small percentage of plutonium (Pu 鈈) in some cases, e.g. Reactor 3 at the Fukushima Dai-ichi Nuclear Plant). The CANDU reactor is the only commercial reactor capable of using un-enriched uranium fuel.

A more recent development is to use MOX.

“Mixed oxide fuel, commonly referred to as MOX fuel, is nuclear fuel that contains more than one oxide of fissile material. MOX fuel contains plutonium blended with natural uranium, reprocessed uranium, or depleted uranium. MOX fuel is an alternative to the low-enriched uranium (LEU) fuel used in the light water reactors that predominate nuclear power generation. For example, a mixture of 7% plutonium and 93% uranium reacts similarly, although not identically, to LEU fuel.

“One attraction of MOX fuel is that it is a way of utilizing surplus weapons-grade plutonium, which would otherwise be stored as nuclear waste and might be stolen to make nuclear weapons. On the other hand, some fear that normalising the global commercial use of MOX fuel and the associated expansion of nuclear reprocessing will increase, rather than reduce, the risk of nuclear proliferation.”[3]

“Most BWR and PWR commercial reactors use uranium enriched to about 4% U-235, and some commercial reactors with a high neutron economy do not require the fuel to be enriched at all (that is, they can use natural uranium). According to the International Atomic Energy Agency there are at least 100 research reactors in the world fueled by highly enriched (weapons-grade/90% enrichment uranium). Theft risk of this fuel (potentially used in the production of a nuclear weapon) has led to campaigns advocating conversion of this type of reactor to low-enrichment uranium (which poses less threat of proliferation).”[4]

In any case, plutonium or uranium, weapon or non-weapon grade, used in nuclear power reactors generate waste. Storing the waste properly is already a global concern

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[3] “MOX fuel”, Wikipedia, http://en.wikipedia.org/wiki/MOX_fuel

[4] “Nuclear reactor technology”, Wikipedia, http://en.wikipedia.org/wiki/Nuclear_reactor_technology

because of its radioactivity and health hazards. Turning the waste into potential material for manufacturing weapons is a very different story.

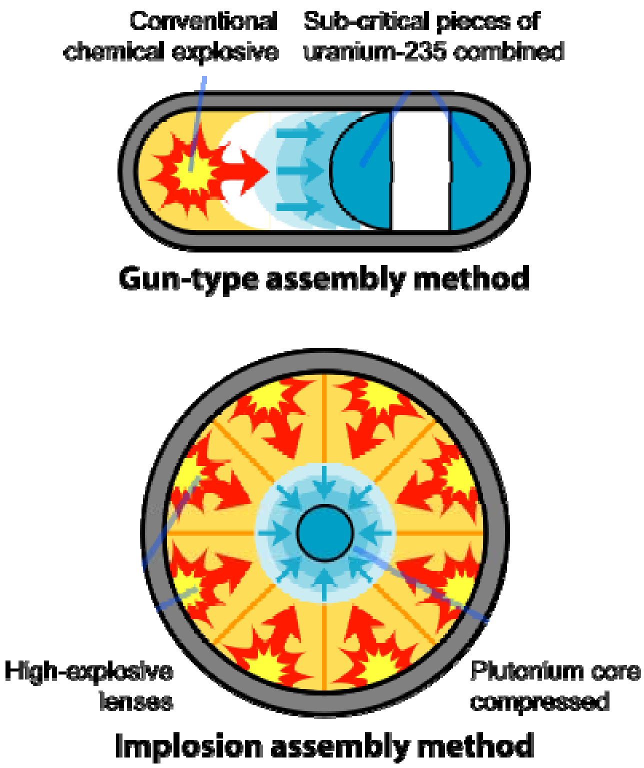
4. Nuclear weapons

Nuclear weapons consist of two forms: (1) fission (atomic bombs – A-bombs); and (2) fusion (hydrogen bombs).

To manufacture A-bombs, U-235 is the most common material. Plutonium-239 is another choice.

Uranium has six isotopes in nature: including U-238 (99%) and U-235(<1%). Uranium-238 is fissionable by fast neutrons, and can be transmuted to fissile plutonium-239 in a nuclear power reactor.

Plutonium is a synthetic element not found in nature in appreciable quantities (Pu-244 is only located in traces). In recent history, plutonium was first synthesized in 1940 by a team in a US laboratory by bombarding uranium-238 with deuterons. Hence Pu-239 is a derivative as a result of reprocessing against uranium. Two A-bombs were thrown by the US (after the Manhattan project) over Hiroshima (uranium based “Little Boy”) and Nagasaki (plutonium based and codenamed “Fat Man” after Winston Churchill) in 1945.



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

Irrespective of the fuel for a nuclear power reactor (plutonium, uranium or MOX), the waste after generation of electricity (usually including plutonium, mainly Pu-240) does not seem to be immediately a potent source for generating weapon-grade constituents. Of course, there have been debates about that issue and conspiracy theory flows around.

As urnaium-235 and plutonium-239 do not exist in appreciable volumes in nature, they have to be generated through process of "enrichment" (isotope separation through diffusion or dentrifuge techniques) and "by bombarding uranium with deuterons" etc. producing depleted uranium DU and weapon-grade plutonium.

These procedures cannot easily be incorporated into traditional BWRs or PWRs. As for a CANDU reactor, non-enriched uranium is the norm. Reprocessing plants are needed.

Since these complicated problems and their implications are outside my best understanding, I would defer to a report by AP[5] and a piece I received through my friends, which was written by Prof. Chiu Hong-Yee.[6]

5. The greatest quake of all time?

Let's go back to Mother Nature. The most intriguing volcano is called caldera, or cauldron. It is a "cooking pot" down below land surface and formed after previous eruption and land collapse. The term was coined by the German geologist Leopold von Buch in the early 19th century.[7]

Calderas can be explosive or non-explosive. Non-explosive ones include the "subsidence" versions in the tourist islands of Hawaii and they were formed in different manners. An explosive one would be a vast reservoir where silica-rich magma is fed and might unleash apocalyptic force. It is sometimes called a super-volcano. It could look inactive for a very long time, but when it erupts … .

The last eruption of a super-volcano was in Lake Toba, Sumatra, between 69,000 and 77,000 years ago, and had thousand times the explosive force of an average earthquake. It plunged earth into a 6-to-10-year volcanic winter, resulting in a reduction of global human population to 10,000 or even a mere 1,000 breeding pairs, creating a bottleneck in the evolution of homo sapiens. Some researchers argue that it produced not only a calamitous volcanic winter but also an additional 1,000-year cooling episode. (http://en.wikipedia.org/wiki/Toba_catastrophe_theory)

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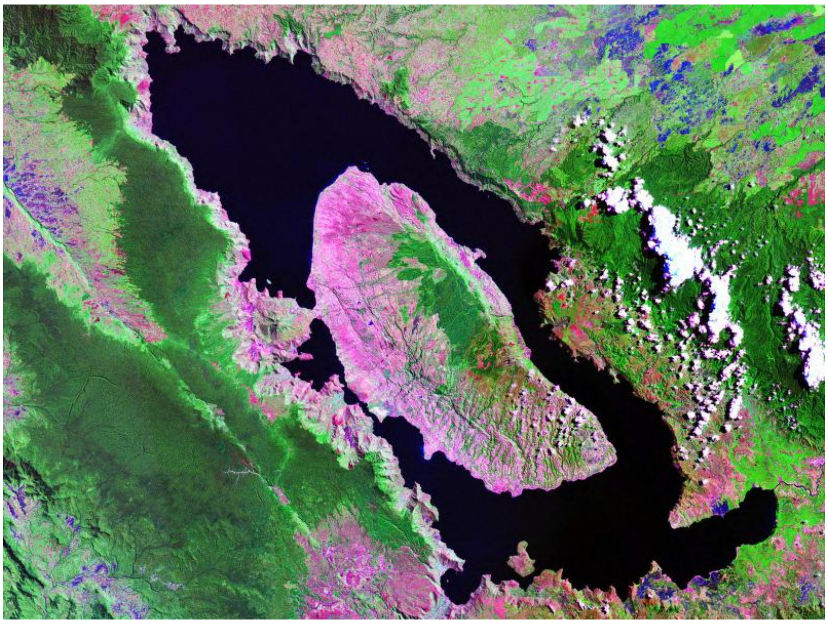
5 "Plutonium in troubled reactors, spent fuel pools", 18/3/2011, Associate Press (http://news.yahoo.com/s/ap/20110318/ap_on_re_as/as_japan_earthquake_plutonium).

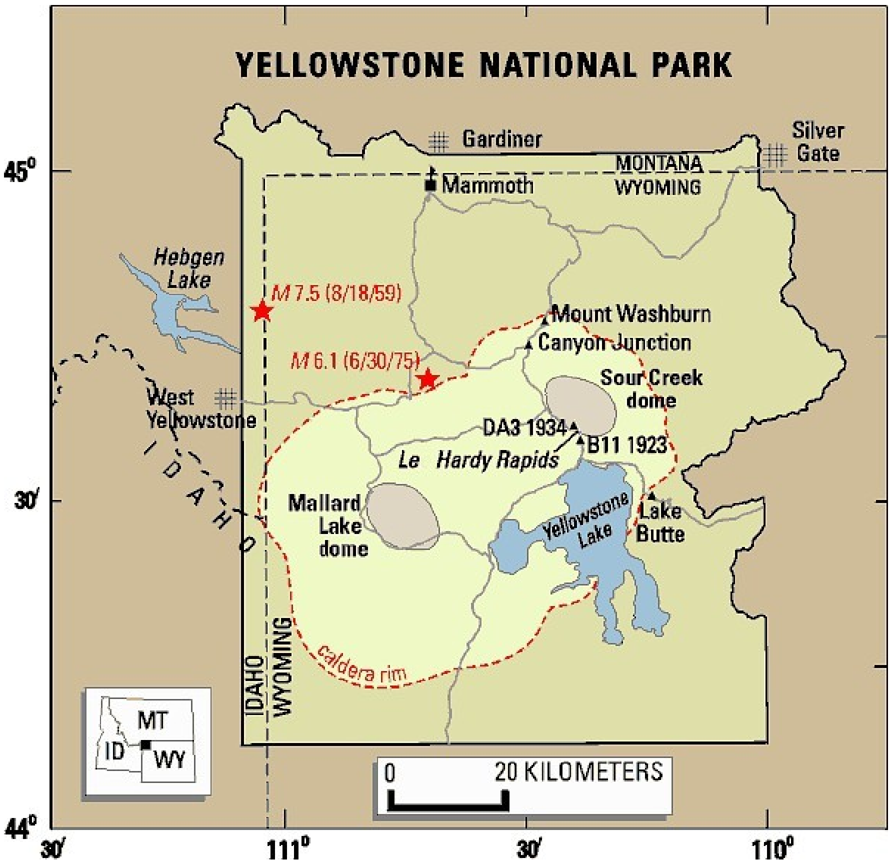
6 Please refer to "A note from e-mail" (www.sktsang.com/ArchiveIII/Japan.pdf). I do not know Prof. Chiu personally.

7 A list of calderas can be found in "Caldera", Wikipedia (http://en.wikipedia.org/wiki/Caldera#List_of_volcanic_calderas)



http://en.wikipedia.org/wiki/File:Toba_zoom.jpg

The “Yellowstone Caldera” is now the largest active volcanic caldera in the world, located in the Yellowstone National Park in the United States**,** with the core in the northwest corner of Wyoming.



http://volcanoes.usgs.gov/yvo/activity/monitoring/lvlmap.php

It measures roughly 50 Km long, 30 Km wide and 10 Km deep; and is filled with dissolved gasses at enormous pressure. It was formed as a result of several huge eruptions and related land collapse dating more than 600,000 years ago.

Researchers have reported that activity in the super-volcano has been rising at a record rate from 2004 onwards. Its floor has gone up three inches per year for the three years since, indicating the fastest rate after records began in 1923 (http://www.earthmountainview.com/yellowstone/yellowstone.htm).

Of course, that in itself does not imply much. Calderas rise and fall over thousands and tens of thousands of years. The US Geological Survey maintains the Yellowstone Volcano Observatory at the University of Utah. Nothing abnormal was reported by April 2010.

It also stated that the period of accelerated Yellowstone caldera uplift beginning in 2004 ended in 2010. The amount of observed subsidence, about 3 cm, was roughly 1/8 of the uplift in that period (http://volcanoes.usgs.gov/yvo/activity/index.php).

6. A caveat

I am neither a geologist nor a nuclear scientist. Indeed I know rather little about both subjects. The Japanese disaster raised so many questions in my mind; and email exchanges with friends aggravate my concerns as people have very strong but contrasting views.

I have tried my best to record some “facts” and form a set of questions. I don’t have reliable answers to them. My hope is that the “facts” are not wrong outright and the questions are not too stupid. Not much more could be asked from a layman, as I like to comfort myself.

However, in a civil society, transparency of information and dissemination of knowledge serve as the necessary social ingredients. If the authorities don’t facilitate the processes, we have to form our opinion and voice questions. Don’t we?