

The End of the World



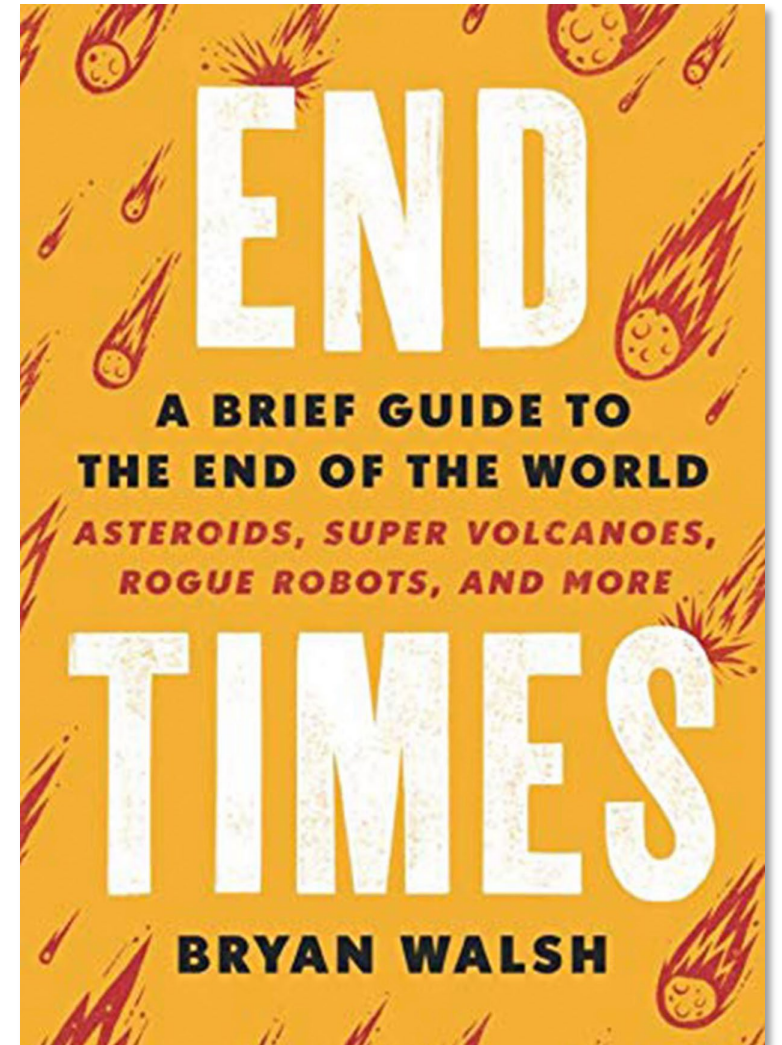
Supervolcanoes
& Nuclear Threats

Week 9 Lecture | Professor Crews
Religious Studies 357 W

In *End Times: A Brief Guide to the End of the World*, author Bryan Walsh takes us through a wide range of possible end of the world scenarios, from asteroids and super volcanoes to killer robots and climate apocalypse.

Walsh is interested not only in what some of the more common end times scientific worries are, but also, how realistic these threats are and what we can do to address them. As he noted in the introduction to his book:

“If we don’t appreciate the present, it’s in part because we don’t fully understand the past— even as we make the mistake of assuming the future will be like the present... Risks that are most available to the mind are the ones that we care about, which is why so much of our regulation is driven by crisis, rather than by reason.”



There have been a number of major volcanic eruptions over Earth's history, and as Bryan Walsh argues, of all the potential natural risks we face, volcanoes are by far the most common and deadly, as evidenced by the "supereruption" of Toba on the Indonesia island of Sumatra 74,000 years ago.


The Toba eruption remains the single largest volcanic event in the last 100,000 years, with an estimated 9 million tons of sulfuric rock and dust per second spewing from the volcano over 2 weeks, with as much as 700 m³ of volcanic ash and magma ejected into the air. While the 1980 eruption of Mt. Saint Helens in Washington was the largest such event in the US, Toba was equal to 2,800 Mt. Saint Helens eruptions!

*"At a moment when *Homo sapiens* was far from the world-dominating force we are today, Toba was our ultimate trial. It was also a warning—the most dangerous natural existential risk we face comes not from the skies above us, but from the ground beneath our feet."*

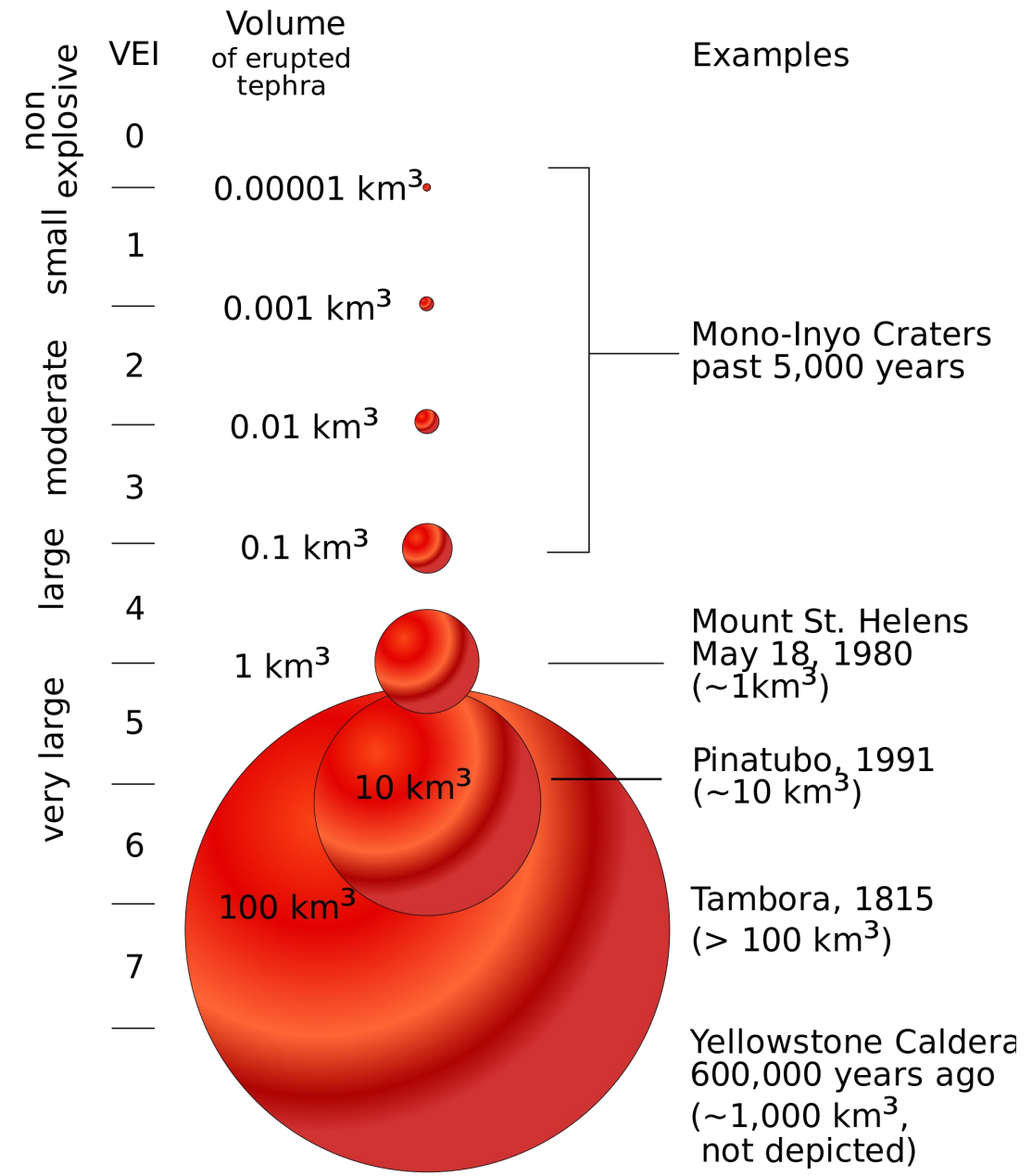
Scientists estimate impacts from Toba's explosion may have included global temperature drops ranging between 18 and 30 degrees for several years. It also led to major declines in rainfall, which would have impacted vegetation globally and severely threatened early *Homo sapiens*. As Walsh notes, *"Imagine a winter that lasted for years, like something out of *Game of Thrones*..."*

Volcanic Explosivity Index

VEI	Description
0	Effusive
1	Gentle
2	Explosive
3	Catastrophic
4	Cataclysmic
5	Paroxysmic
6	Colossal
7	Super-colossal
8	Mega-colossal

(Supervolcano) 

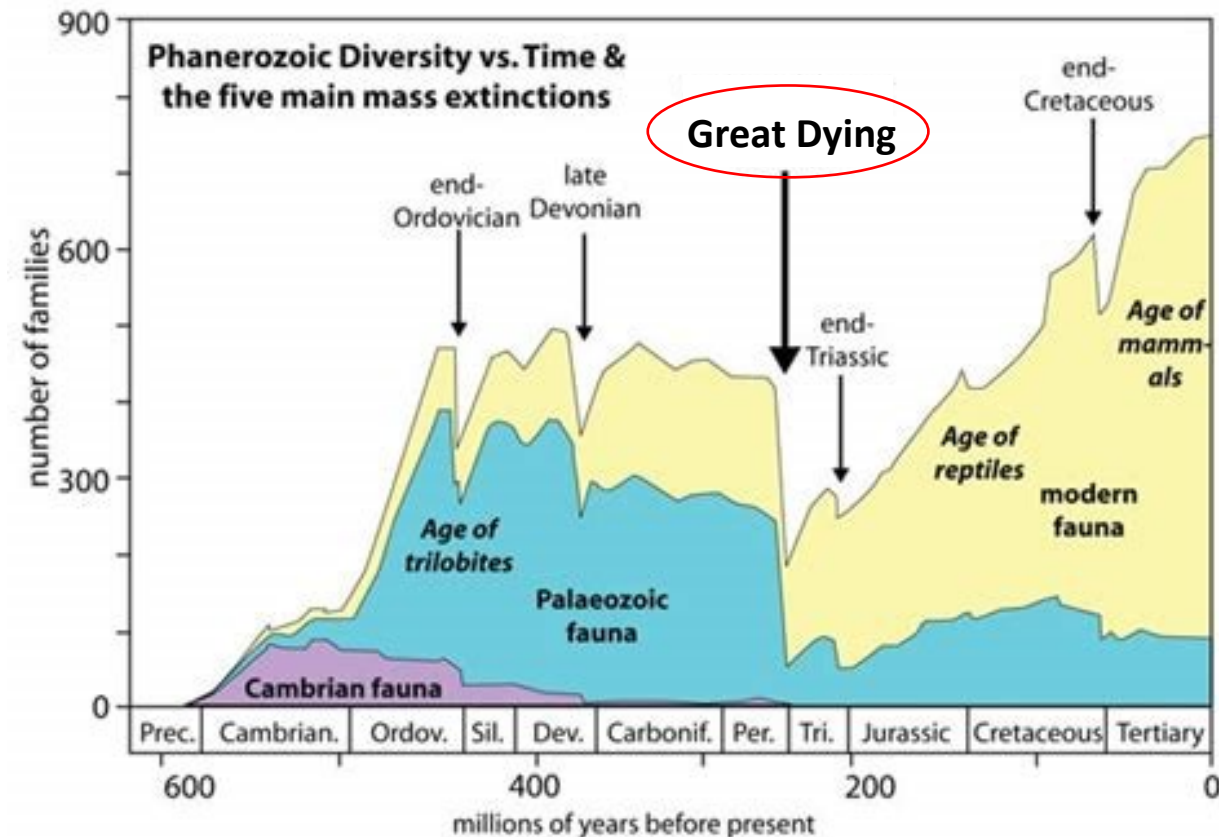
The destructive power of volcanoes is measured using the Volcanic Explosivity Index (VEI), a ranked scale from 1-8 that was developed in 1982 after the eruption of Mt. Saint Helens in Washington (1980).



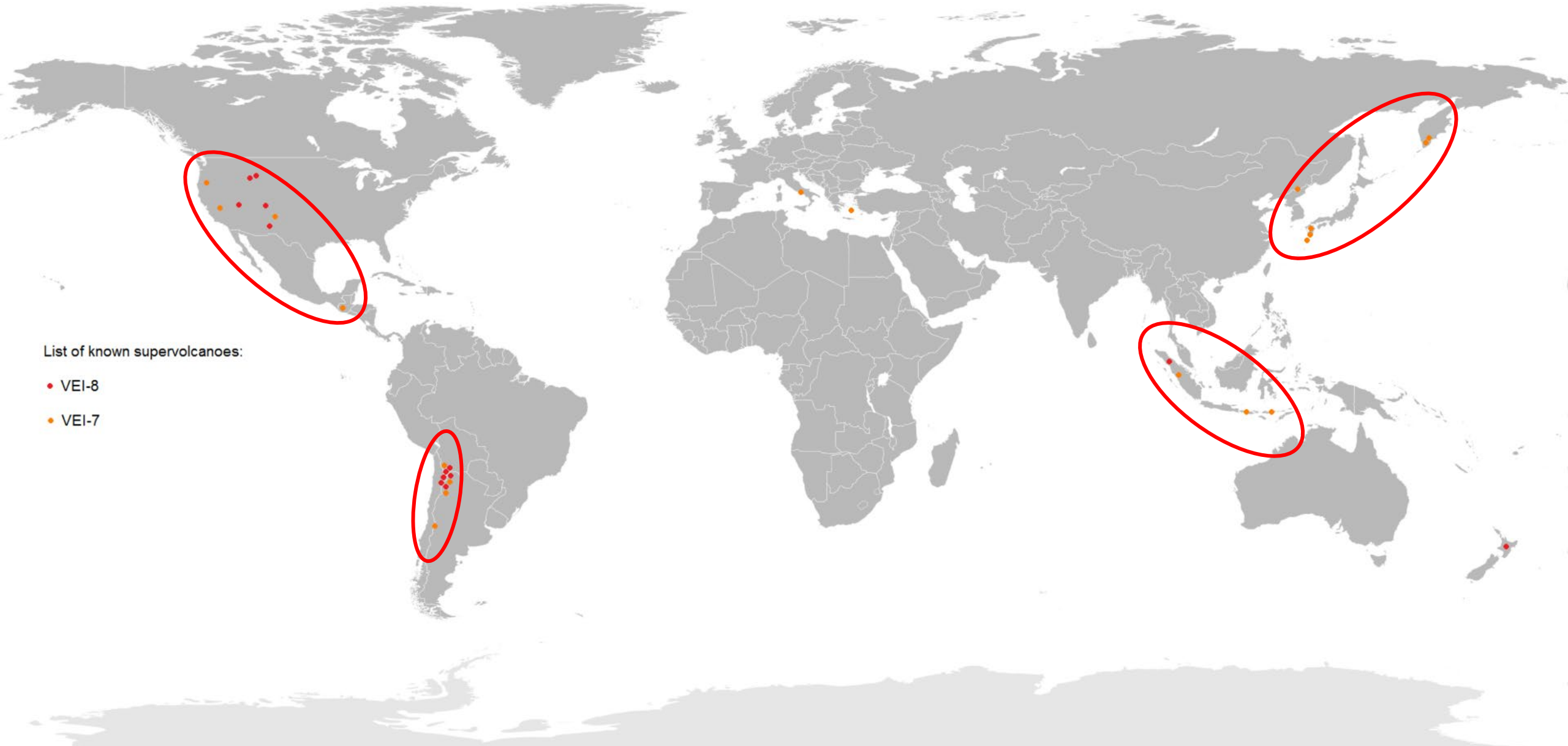
Sci Show

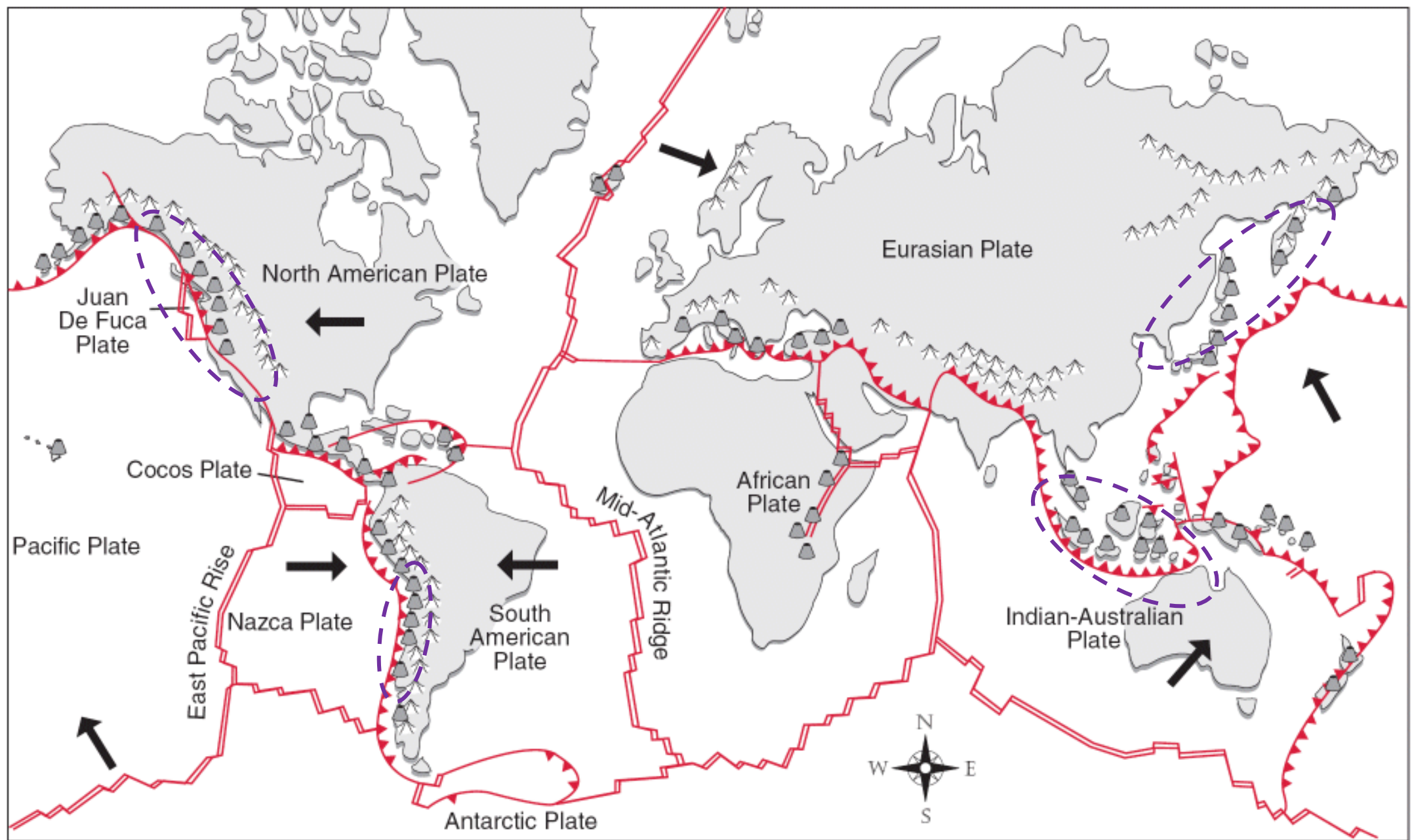
We discussed the 5 mass extinction events in Earth's past in previous weeks. By far the most significant of these was the End Permian Extinction Event (Permian-Triassic Extinction), aka the "Great Dying." This occurred around 250 million years ago and was linked to volcanic activity in the Siberian Traps. The impact of numerous massive volcanic eruptions over hundreds of thousands of years across a vast part of Siberia led to rapid changes in the air, water, and chemical makeup of the planet. The result of these changes was the extinction of more than 70% of life on land and 90% of life in oceans.








"If Toba marked the moment when humanity was nearly driven to extinction, the Great Dying nearly ended the story of life altogether. And both began with a volcano— a reminder that, as the historian Will Durant wrote, "Civilization exists by geological consent, subject to change without notice." No natural force on Earth puts humans at greater existential peril than a supervolcano."



Supervolcanoes around the world





- | | | | |
|--|--|--|---|
|  Divergent boundary |  Convergent boundary |  Transform boundary |  Mountains |
|  Supervolcanoe area |  Plate movement relative to the African Plate |  Volcanoes | |

One challenge in better understanding global impacts of a modern supervolcanic eruption is the sheer level of uncertainty. Because the location, timing, magnitude, and duration of volcanic eruptions vary widely, it is hard to build precise models that can account for everything from global climate change to disrupted ecosystems and collapsed economies. Also, the models we do have are based on the past, which as Bryan Walsh notes, tells us nothing about the future.



“That’s an occupational hazard of dealing in existential risk. We look to past analogues to try to forecast how a future event will unfold, but existential risks by definition are on a level that we have never known.”

A case in point is Mount Tambora, the volcanic eruption that took place in Indonesia on April 5, 1815 and had profound impacts all around the world. No one at the time could have predicted the ramifications that the eruption of Tambora would have. Indeed, many of the impacts weren't apparent until decades or centuries later, as scientists gained a more comprehensive understanding of the 1815 eruption.

Tambora was a VEI 7 eruption, the most powerful and deadly volcanic event in recorded human history, and with an estimated 100,000 deaths.

The plume of volcanic ash circled around the world, disrupting weather and leading 1816 to be called the "Year Without a Summer." Average temperatures dropped by 2.7 degrees (1810-1819), the coldest decade in historical records. Epidemics of cholera and typhus in Europe added to mass starvations and crop failures sweeping through Europe, Asia and the Americas. Things were so bad in parts of Europe that immigration to the US more than doubled between 1816 and 1817, while tens of thousands of settlers headed west across the Appalachian mountains in search of warmer weather and better farming land.

“What Tambora and the other eruptions of its class teach us is that volcanoes can have global effects, ones that continue well after the volcano itself has fallen silent. A volcanic change to the climate can cause starvation, massive refugee flows, even political revolts. We can't prevent a volcano erupting—at least not yet. But we can control how our society responds to the shock of a catastrophe...”

“In the summer of 1816, we visited Switzerland, and became the neighbours of Lord Byron...But it proved a wet, ungenial summer, and incessant rain often confined us for days to the house. Some volumes of ghost stories...fell into our hands...“We will each write a ghost story,” said Lord Byron.”



How can I describe my emotions at this catastrophe, or how delineate the wretch whom with such infinite pains and care I had endeavoured to form? His limbs were in proportion, and I had selected his features as beautiful. Beautiful!—Great God! His yellow skin scarcely covered the work of muscles and arteries beneath; his hair was of a lustrous black, and flowing; his teeth of a pearly whiteness; but these luxuriances only formed a more horrid contrast with his watery eyes, that seemed almost of the same colour as the dun white sockets in which they were set, his shrivelled complexion and straight black lips.

Chapter 1st 21/45
It was on a dreary night of November
that I beheld my ~~man~~ ^{the frame} completed, and
with an anxiety that almost amount-
ed to agony, I collected my implements of life
around me, and ~~endeavoured~~ ^{tried} to infuse a
spark of being into the lifeless thing
that lay at my feet. It was already
one in the morning, the rain pattered
dismally against the window-pane, &
my candle was nearly burnt out, when
by the glimmer of the half-extinguish-
ed light I saw the dull yellow eye of
the creature open. It breathed hard,
and a convulsive motion agitated
its limbs.
But how ~~how~~ ^{how} can I describe my
emotion at this catastrophe, or how deli-
neate the wretch whom with such
infinite pains and care I had endeavoured
to form. His limbs were in proportion
^{beautiful} and I had selected his features as
~~beautiful~~ ^{beautiful}. ~~Beautiful!~~ ^{Beautiful!} Great God! His
yellow skin scarcely covered the work of
muscles and arteries beneath, his hair
was ^{of a lustrous black} flowing and his teeth of a pearly white-
ness; but these luxuriances only ~~formed~~
formed a more horrid contrast with
his watery eyes that seemed almost of
the same colour as the dun white
sockets in which they were set,

Excerpt from Shelley's 1816 handwritten draft of Frankenstein.

Here in the United States, the main supervolcano risk that we would need to worry about is Yellowstone, which saw three major eruptions over the past 2.1 million years. While the risk of the Yellowstone volcano erupting today are low (0.00014 % or 1 in 730,000), it remains the most likely catastrophic natural disaster that we would face in the US. One FEMA study estimated that a Yellowstone supervolcanic eruption could cost the US upwards of \$3 trillion in economic damages and potential destruction of much of the Midwest.

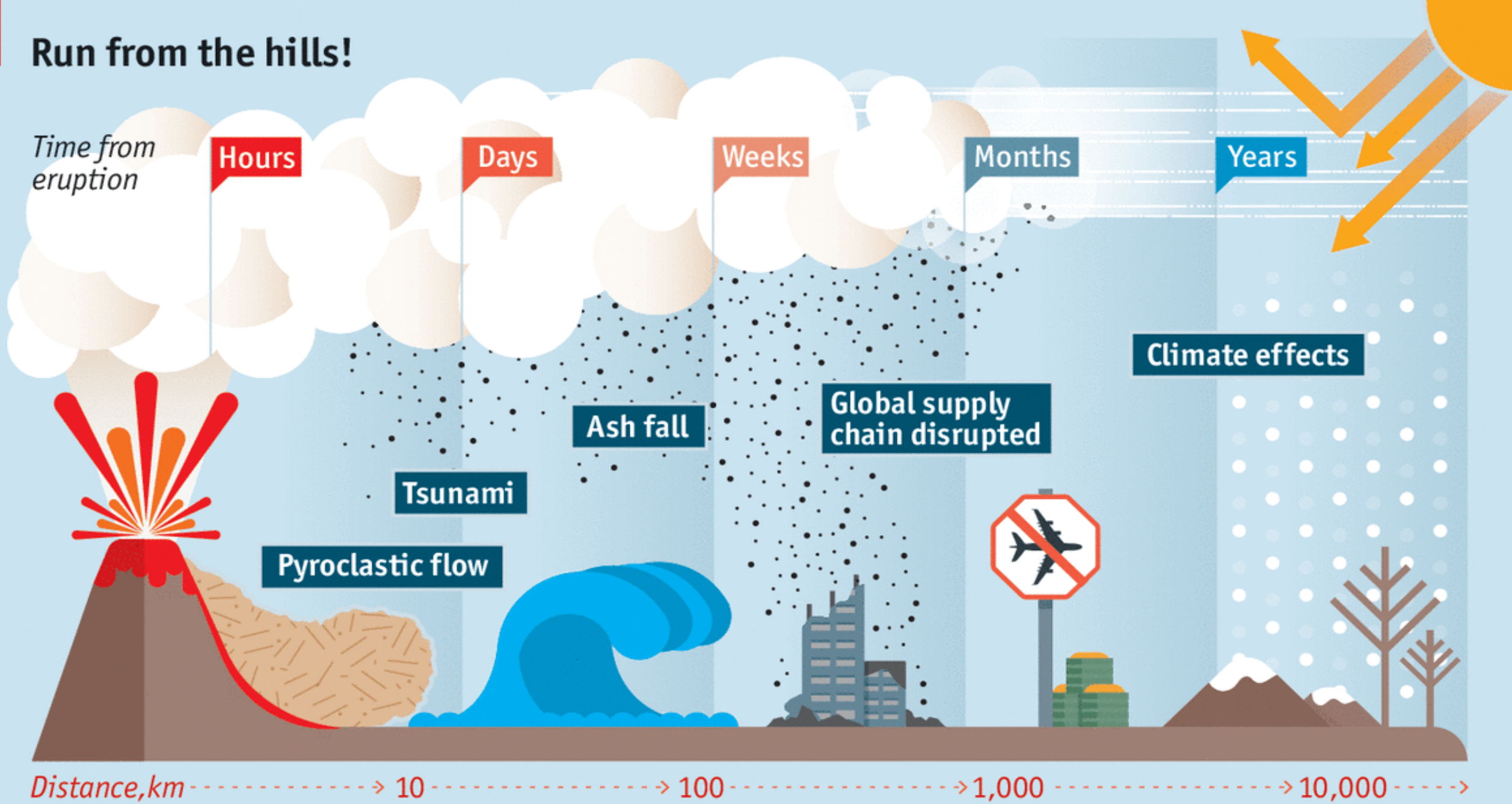
But the impacts would not be limited to only the US. With the collapse of the Midwest grain belt, as much as 50% of the global grain supply would vanish overnight. Disruptions to electrical and transportation systems could effectively put large parts of the US into a prolonged power blackout, possible lasting years.

The volcanic ash fallout would not only render agricultural soils unfit for use, volcanic ash (tephra) would reek havoc on water and air filtration systems, further compounding public health problems. A 2006 study predicted a Yellowstone supervolcano could cause global temperatures to drop by as much as 18 degrees, with effects lasting for as long as a decade afterwards.

“In every past catastrophe—hurricanes, earthquakes, floods—most of the US remained untouched, which meant safe parts could divert aid to take in refugees from affected regions. But no corner of the continental United States would be exempt from the effects of a supervolcano...Volcanoes have caused mass extinction on this planet before; in fact, they are the serial killers of life.”

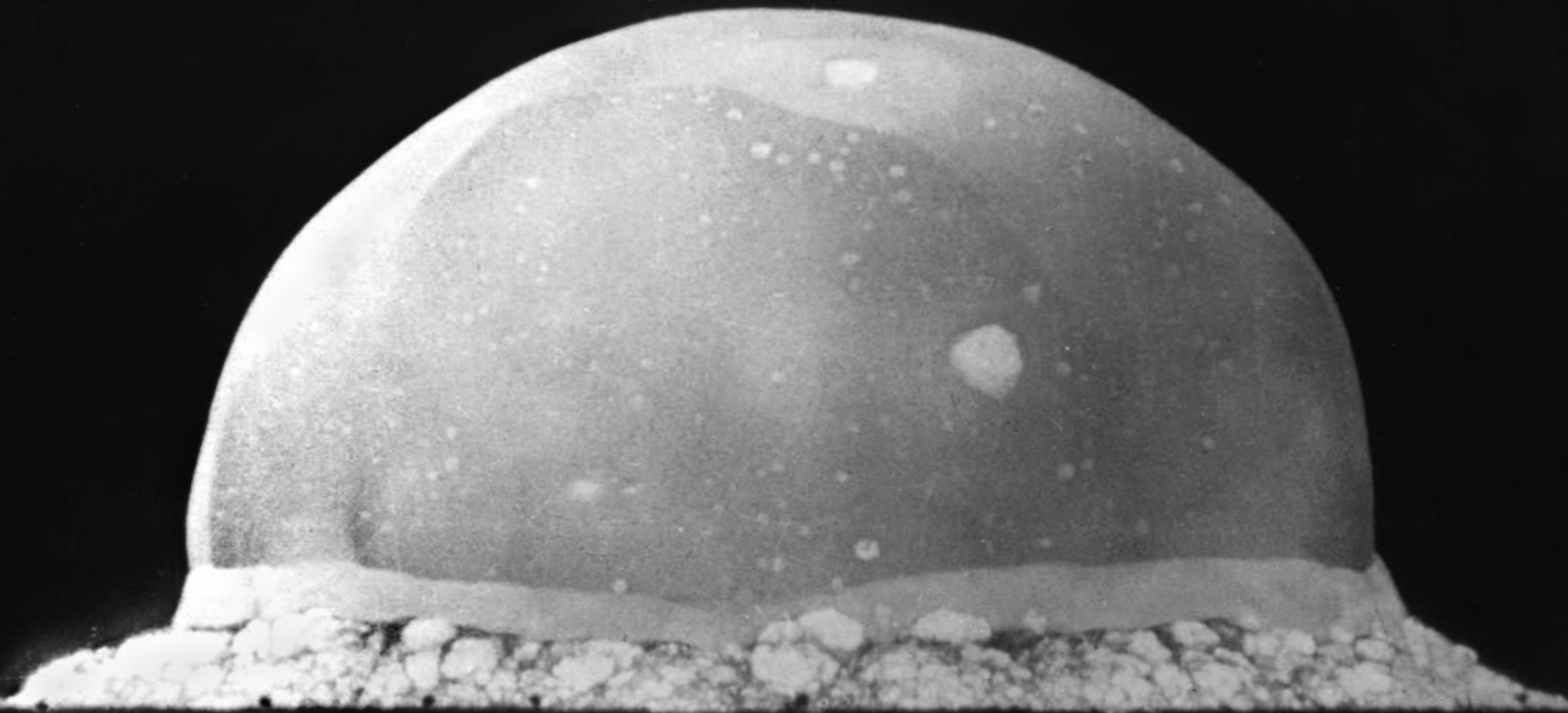


Run from the hills!

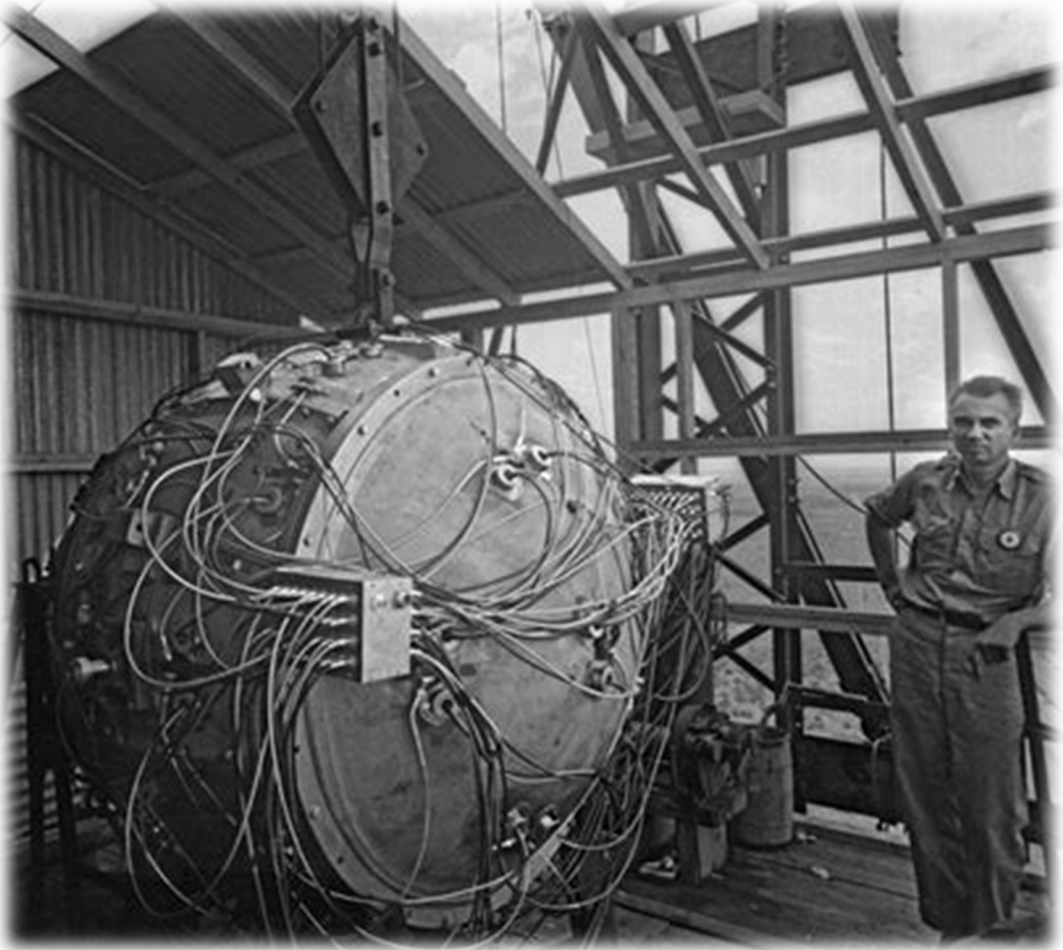


Source: *The Economist*

Trinity nuclear explosion 0.025 seconds after detonation. July 16, 1945



Our nuclear story begins at the Trinity Site in New Mexico on July 16, 1945 at 5:30 am when scientists with the Manhattan Project successfully tested the first atomic bomb in human history. The test was the result of nearly four years of research by hundreds of scientists working in secret.



The "Gadget" containing the first atomic bomb.



"Zero" tower.



Trinity Site "Ground Zero" monument.

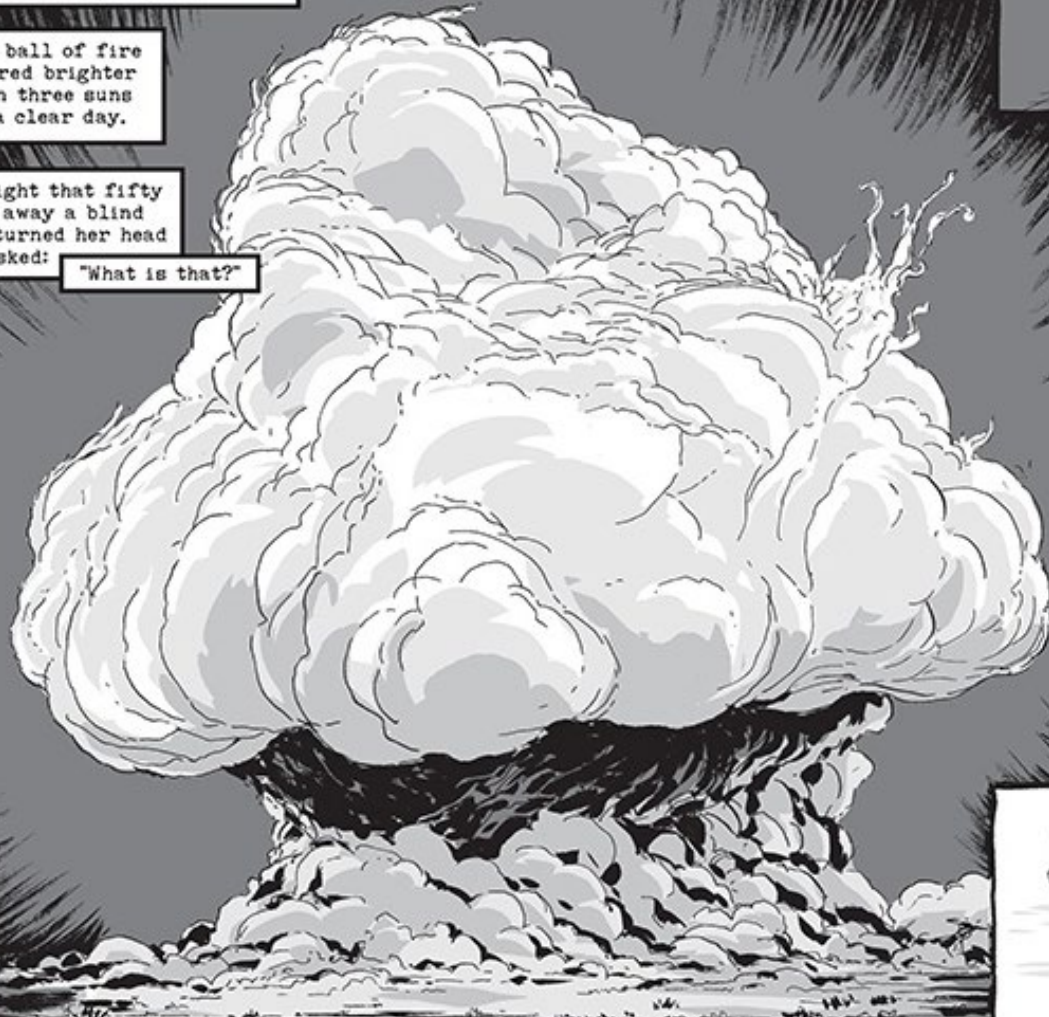
The darkened eyes of observers in the command center, more than five miles away, saw a sudden flash to the east.

The glow of the atmosphere burning like the filament of a lightbulb.

The ball of fire glared brighter than three suns on a clear day.

So bright that fifty miles away a blind girl turned her head and asked:

"What is that?"



The orb rose, roiling into the sky, sloughing off radioactive skirts of purple, blue, scarlet, green.

Oppenheimer, speaking years later, recalled his reaction:



"WE KNEW THE WORLD WOULD NOT BE THE SAME."



"A FEW PEOPLE LAUGHED, A FEW PEOPLE CRIED."

"MOST PEOPLE WERE SILENT."



"I REMEMBERED THE LINE FROM HINDU SCRIPTURE, THE BHAGAVAD GITA..."



"NOW I AM BECOME DEATH,"

"THE DESTROYER OF WORLDS."

The test had added urgency since US President Harry Truman was scheduled to meet the next day with Soviet premier Joseph Stalin at the Potsdam Conference. Although Truman did not tell Stalin about the successful test until a week later, we now know that Stalin was already aware of the successful July 16 test thanks to Russian spies who had briefed the premier and smuggled out top-secret details about its construction.

Truman wrote the following reflections in his journal on July 17, 1945 after his meeting with Stalin:

“After the usual polite remarks we got down to business. I told Stalin that I am no diplomat but usually said yes and no to questions after hearing all the arguments. It pleased him. I asked him if he had the agenda for the meeting. He said he had and that he had some more questions to present. I told him to fire away. He did and it is dynamite -- but I have some dynamite too, which I am not exploding now.”

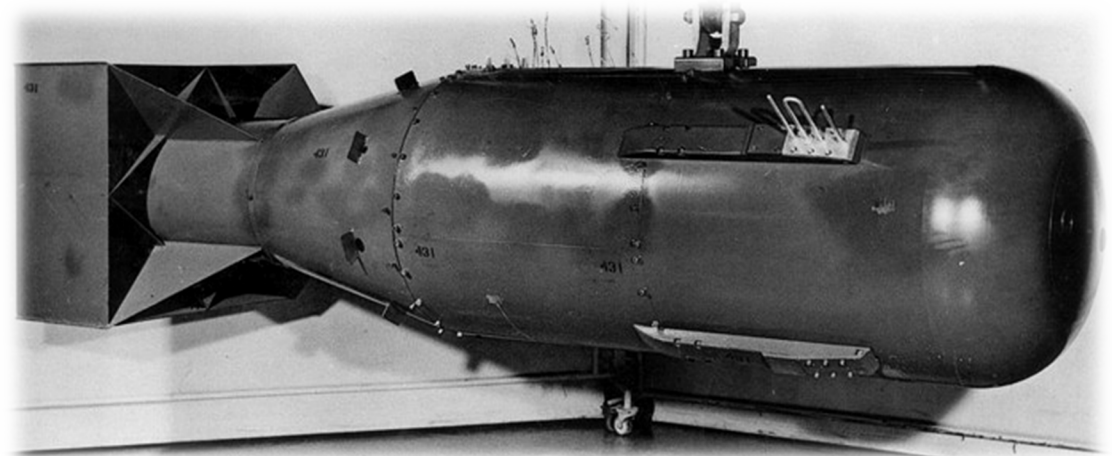


Reflecting on news of the successful tests the following week, Truman wrote on July 25, 1945:

“We have discovered the most terrible bomb in the history of the world. It may be the fire destruction prophesied in the Euphrates Valley era, after Noah and his fabulous ark.

An experiment in the New Mexico desert was startling -- to put it mildly. Thirteen pounds of the explosive caused a crater six hundred feet deep and twelve hundred feet in diameter, knocked over a steel tower a half mile away, and knocked men down ten thousand yards away. The explosion was visible for more than two hundred miles and audible for forty miles and more...It seems to be the most terrible thing ever discovered, but it can be made the most useful.”

The “Gadget” tested at Trinity Site had the explosive force of 22 kilotons, far larger than any previous bombs. The “Little Boy” uranium bomb dropped by the B-29 bomber *Enola Gay* on Hiroshima a week later had the explosive force of 15 kilotons, while the “Fat Man” plutonium bomb dropped on Nagasaki on August 9th had the explosive force of 21 kilotons.



The “Little Boy” nuclear bomb dropped on Hiroshima.

On August 6, 1945 at 8:15 am local time the Enola Gay bomber dropped its “Little Boy” bomb on Hiroshima, denotating the bomb 1,900 feet above the city. The immediate explosion and exposure to the heat instantly killed an estimated 70-80,000 people, or nearly 1/3 of the population. Another 70,000 were injured, with US military estimates suggesting that 69% of the city was destroyed.

Soon after the bombing of Hiroshima President Truman released a public statement on the attacks:

“Sixteen hours ago an American airplane dropped one bomb on Hiroshima, an important Japanese Army base. That bomb had more power than 20,000 tons of T.N.T. It had more than two thousand times the blast power of the British “Grand Slam” which is the largest bomb ever yet used in the history of warfare.

The Japanese began the war from the air at Pearl Harbor. They have been repaid many fold. And the end is not yet. With this bomb we have now added a new and revolutionary increase in destruction to supplement the growing power of our armed forces...I shall give further consideration and make further recommendations to the Congress as to how atomic power can become a powerful and forceful influence towards the maintenance of world peace.”

HOW POWERFUL WAS HIROSHIMA?

When an atomic bomb was dropped on Hiroshima in August 1945, it was the most devastating explosion ever. It started the age of weapons of mass destruction.

LITTLE BOY
15 KILOTONS*

Bomb dropped on Hiroshima (USA)

FAT MAN
21 KILOTONS

Bomb dropped on Nagasaki (USA)

B53
9,000 KILOTONS

Bomb detonated by the USA

CASTLE BRAVO
15,000 KILOTONS

Bomb detonated by the USA

TZAR BOMBA
50,000 KILOTONS

Largest bomb ever detonated (Russia)

IVY KING
500 KILOTONS
Bomb detonated by the USA

CNN SOURCE: USA

Hiroshima
(15 kiloton)



Castle Bravo
(15 Megaton)



B-41 bomb
(25 Megaton)



Tsar Bomba
(50 Megaton)





The shadow of a person disintegrated at the moment of the Hiroshima blast. The steps were removed and put on exhibit at the Hiroshima Peace Memorial Museum.

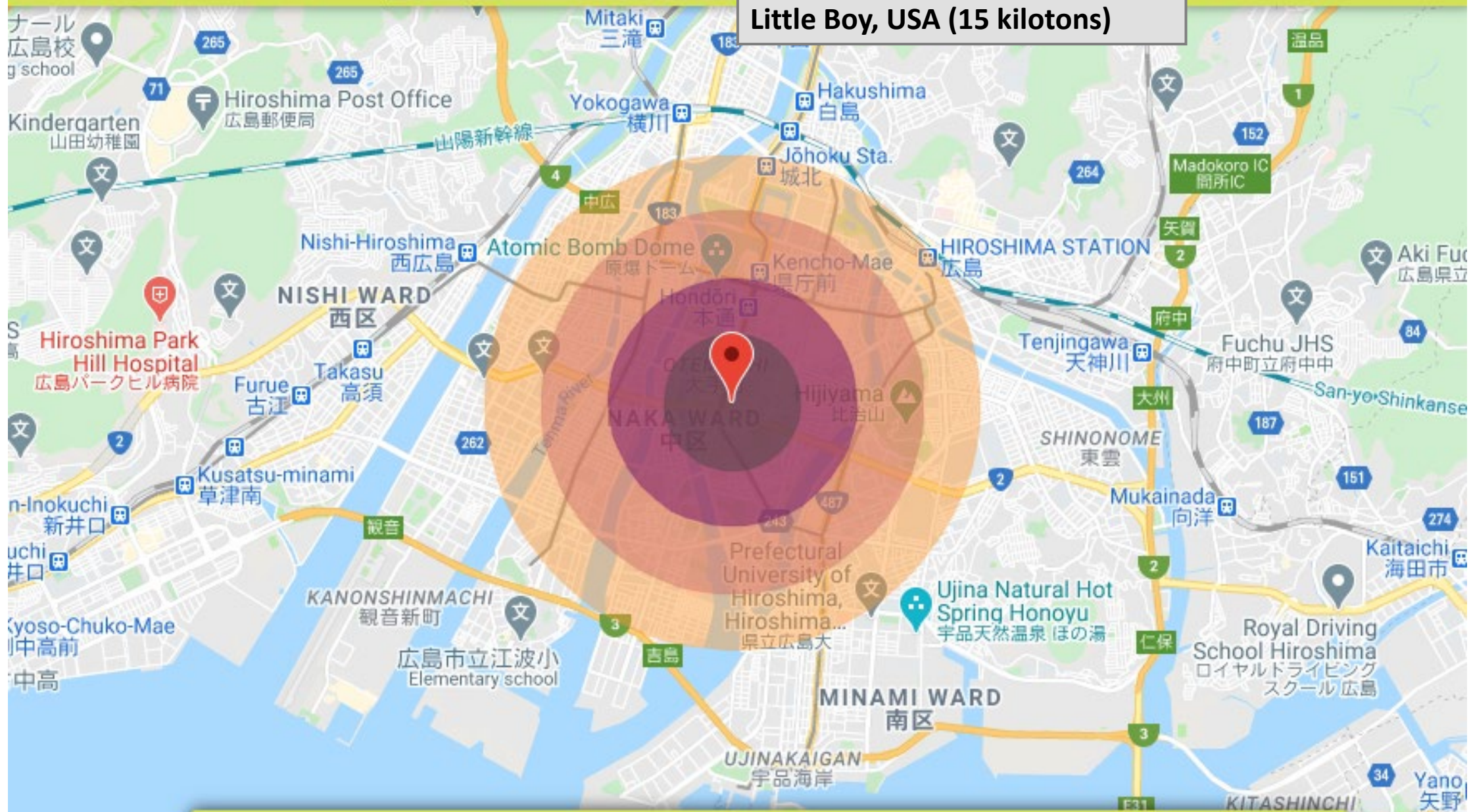
A tricycle 1,500 m from the center of the Hiroshima explosion. Shinichi Tetsutani (3 years, 11 months) was riding the tricycle when the bomb exploded. Suffering serious injuries and burns all over his body, he died that night.



Hiroshima, Japan

Select a weapon here ▾

Little Boy, USA (15 kilotons)

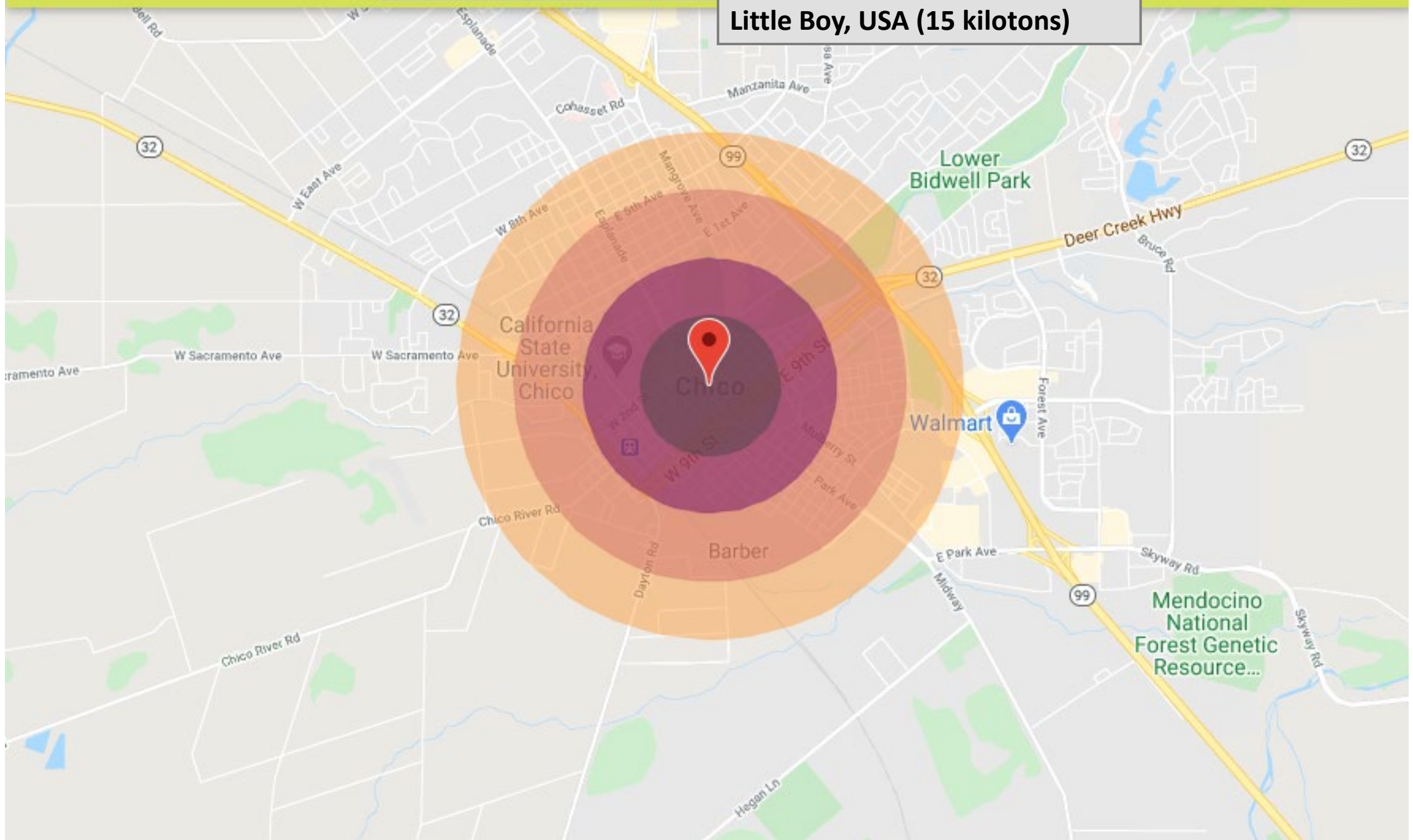


1945, USA, The uranium Hiroshima bomb was the first device used in war.

Chico, California

Select a weapon here ▾

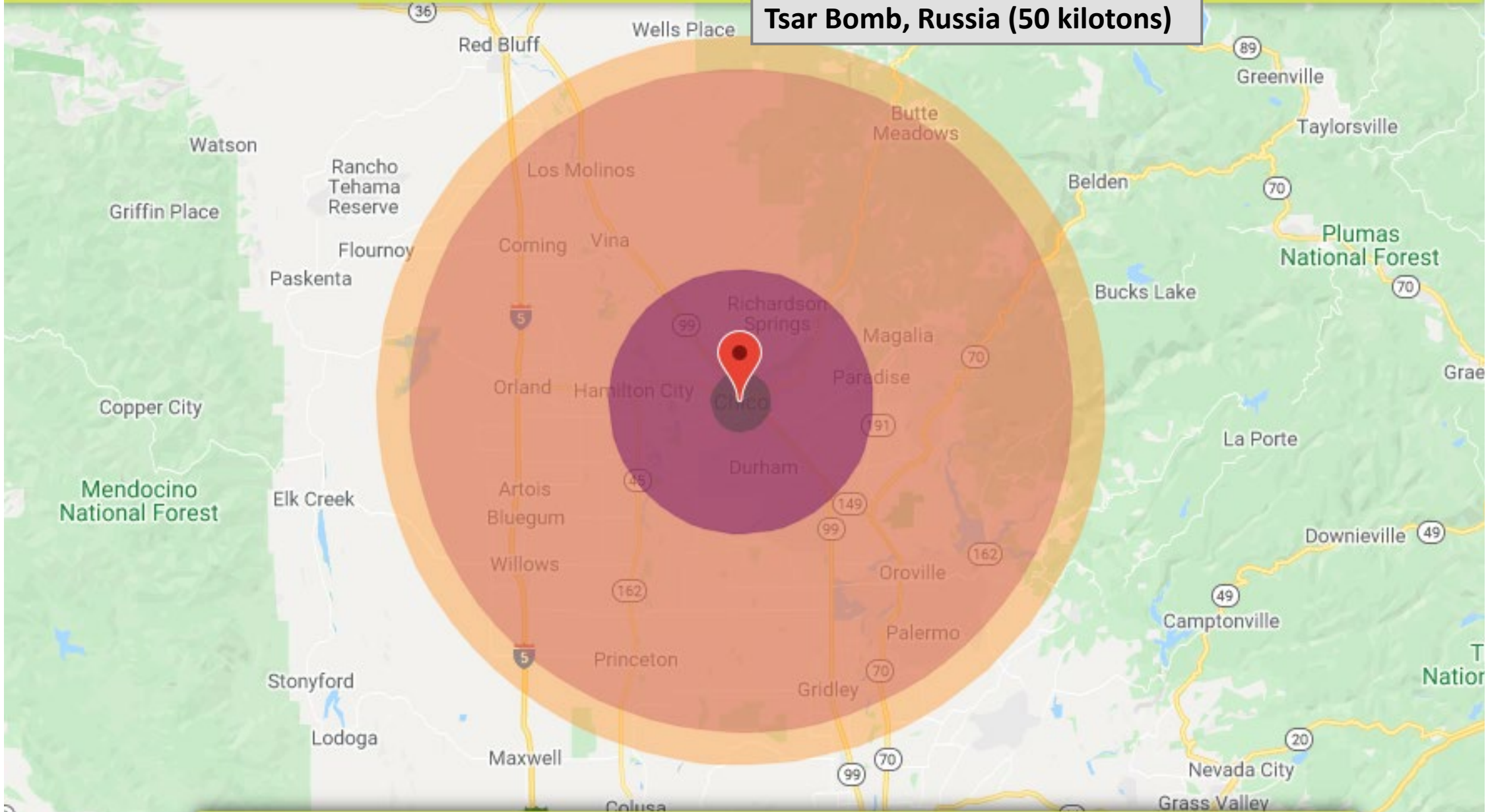
Little Boy, USA (15 kilotons)



Chico, California

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Tsar Bomb, Russia (50 kilotons)

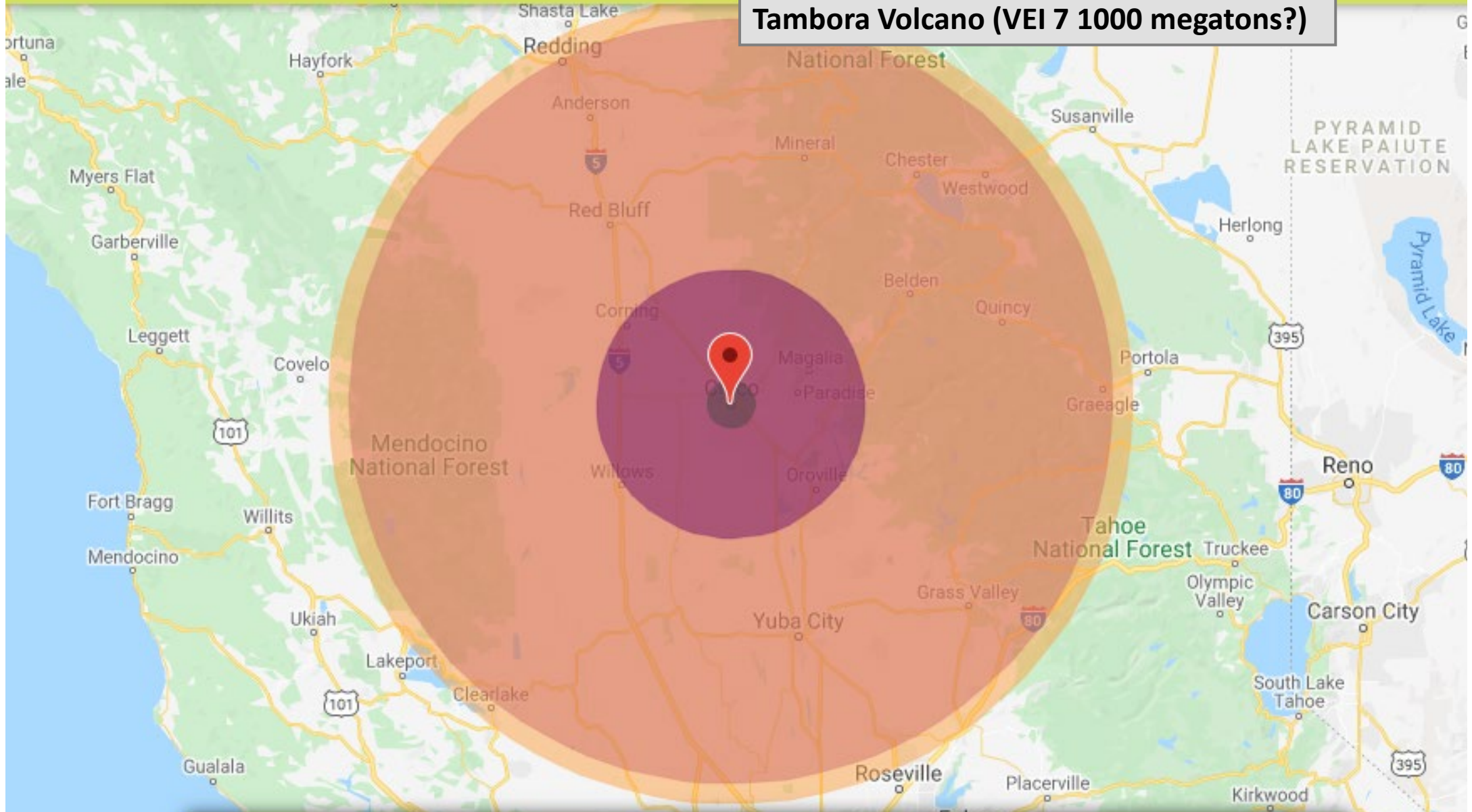


1961, USSR, The largest man-made explosion ever recorded in history.

Chico, California

Select a weapon here ▾

Tambora Volcano (VEI 7 1000 megatons?)



1815, Geological Event, A devastating eruption that cooled the world for a year.



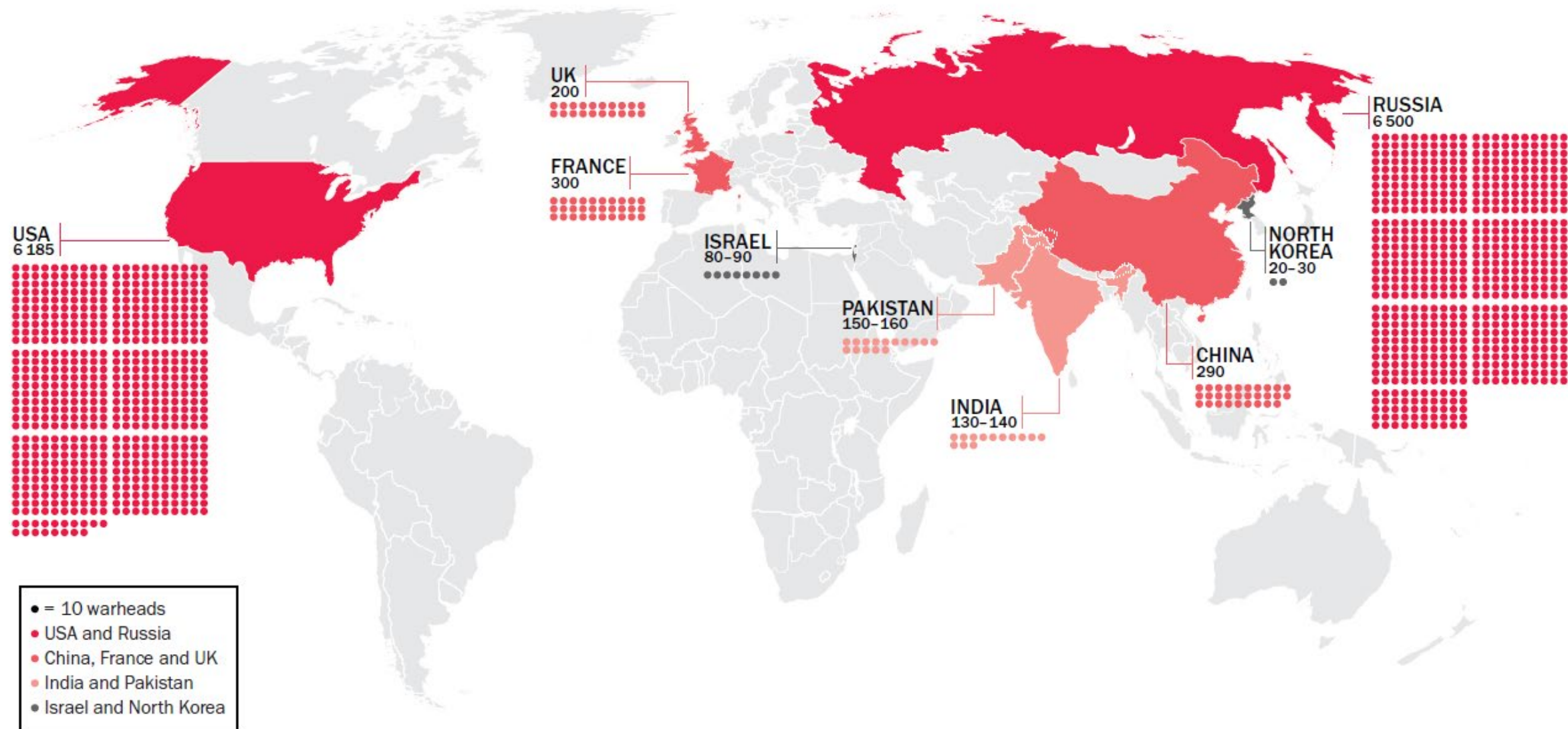
As Bryan Walsh reminds us, “Scientists move civilization forward through their pursuit of knowledge, but Trinity demonstrated that their pursuit can inadvertently create the conditions for our own doom. Existential threats can be brought into the world not by those who wish to end it, but by those who hope to better it. Intentions don’t matter for the fate of the world— results do.”

The revelation that the US had finally developed nuclear weapons led to the start of a global arms race, with Russia detonating their first nuclear bomb in 1949, followed by Great Britain in 1952, France in 1960, and China in 1964. Later additions now include India, Pakistan, North Korea, and Israel, although Israel has never publicly confirmed or tested its weapons.

The Stockholm International Peace Research Institute’s (SIPRI) 2019 Yearbook estimated global nuclear stockpiles at 13,865 weapons, with around 3,700 in active deployment. Over 90% of these are held by the US and Russia.

The nuclear arms race that began in the 1950s as the Cold War was beginning to take shape provided the cultural context that we explored at the beginning of this course when we looked at how Cold War politics drove the backyard bunker building craze, or what Bradley Garrett called the “first doom boom.” This period also saw the creation of new governmental institutions like the Federal Civil Defense Administration (FCDA), an early precursor to our modern Department of Homeland Security.

GLOBAL NUCLEAR WEAPON STOCKPILES, 2018





The “Duck and Cover” video nicely captures the cultural dynamics in the US at the start of the Cold War. Yet, as Bryan Walsh reminds us, in the event of an actual nuclear war, such advice was meaningless.

“These plans for what came to be known as civil defense represented what the sociologist Lee Clarke has called “fantasy documents” —exercises that were done to give both the citizenry and the bureaucracy a sense of control, however fantastical, over the uncontrollable.”

We saw similar efforts to gain some semblance of control over uncontrollable situations in our discussing of preppers and disaster preparedness, and how the very act of prepping can help to alleviate fears and provide a positive outlet for an otherwise abstract sense of dread about unseen dangers or threats.

Truman’s hope that harnessing atomic energy would usher in a new era of peace proved naïve at best, and instead led to decades of escalating nuclear proliferation. As we discussed previously, the world has been on the brink of nuclear war several times due to political bluffs and technical mishaps. Were it not for the actions of Russian sub commander Vasili Arkhipov, the 1962 Cuban Missile Crisis could have started WWII.

Even more dangerous, as Bryan Walsh notes, were early US nuclear plans. An armed conflict with the Soviets (or China) would be responded to by firing the entire US nuclear arsenal—which the Pentagon estimated would kill 600 million people. RAND nuclear scholar Herman Kahn called this “megadeath.”

The threats of a possible nuclear war escalated during the 1980s under Reagan thanks to the Strategic Defense Initiative, jokingly referred to as “Star Wars” at the time, which was part of the military logic of the time that came to be known as MAD or Mutually Assured Destruction. The hope was that the risks from a massive nuclear assault on either nation would be enough to deter both countries from launching an attack.

On paper the theory worked, but the reality was that both sides increased their nuclear stockpiles and weapons programs without any thought to the larger global impacts, impacts which increasingly became clear during the 1970s as scientists gained a better understanding of just how destructive a potential nuclear conflict between two superpowers would be for the environment. Walsh notes that “as scientists continued to refine their climate models, those changes in temperature and sunlight began to look less minor and more catastrophic.”

By the early 1980s scientists had a name for this threat—“nuclear winter.” The emerging scientific dangers of a total nuclear conflict were enough to sway both Russian premier Mikhail Gorbachev and US President Ronald Reagan, and by 1986 nuclear stockpiles peaked at around 70,000 weapons and then began to slowly decline, driven in part by fears of a nuclear winter.

This process was further bolstered by the signing in 1987 of the Intermediate-Range Nuclear Force Treaty between the Soviet Union and the United States.

These efforts continued throughout the Cold War, and led to a series of nuclear non-proliferation efforts, such as the 1963 Partial Nuclear Test Ban Treaty and the 1996 Comprehensive Nuclear-Test-Ban Treaty. More recently, former President Obama signed the New Strategic Arms Reduction Treaty (New START) in 2010, which was meant to further curb the potential threats from nuclear weapons.

Recently we have seen a reversal by Washington of these earlier US nuclear non-proliferation policies:

- In July 2015, the Joint Comprehensive Plan of Action (JCPOA) was reached between Iran and UN Security Council member states, more commonly known as the “Iran nuclear deal”. In May 2018, the US announced they were withdrawing, ending all third-party oversight of Iran’s nuclear energy program.
- In October 2018, the US announced it was pulling out entirely from the 1987 Intermediate-Range Nuclear Force Treaty with Russia. The US officially withdrew on August 2, 2019.
- The New START is set to expire in February 2021 unless Congress approves another five-year extension. President Trump has stated the US will not renew the treaty under its current terms.
- US administration has also proposed spending an additional \$1.2 trillion to expand US nuclear weapons over the next thirty years.

In addition to overt military uses, there is also the risks of nuclear contamination, which the 2011 Fukushima Daiichi nuclear disaster in Japan reminded us is a problem with no solution. Last week Japan announced they will be pumping as much as 1 million gallons of treated (but still radioactive) wastewater into the Pacific Ocean. This adds to the growing list of nuclear disasters such as the 1979 Three Mile Island nuclear meltdown in Pennsylvania and the 1986 Chernobyl nuclear disaster in Ukraine.

As Bryan Walsh argued, “What this all means— the changing nuclear posture, the abandonment of arms control treaties, the new weapons— is that the barriers to nuclear war are falling. Tactical, low-yield nukes are seen as “gateway drugs” to full-scale conflict, and expanding the range of attacks the United States might choose to respond to with atomic weapons blurs what should be very sharp lines around nuclear war...firing off a single tactical nuke might seem a lot closer to ordering conventional air strikes— something American presidents rarely hesitate to do when confronted with a range of threats that all fall short of the existential. Once the nuclear seal has been broken, though— even by what seems like a comparatively minor bomb— no one knows what will happen next.”

I think the 1997 report from the Canberra Commission on the Elimination of Nuclear Weapons put it best:

“The proposition that nuclear weapons can be retained in perpetuity and never used— accidentally or by decision—defies credibility.”

Weekly Assignment Reminder

- Remember to check our class Blackboard regularly for updates, announcements, and other related class information...
- Have you done the weekly readings and watched any associated videos? Weekly readings are listed on the Class Schedule page.
- Complete the weekly discussion post response. Initial post due Wed, Oct 21 by end of day, and peer response post due Fri Oct 23 by end of the day.

In these fractions of a second,
the atomic light was still pure.

It was not yet a bomb.

It was not yet a symbol of apocalypse.

It was not yet a
part of our world.

In these fractions of a second,

the atomic light was still as timeless
and indifferent as the universe itself.

