



5. Životnost ložisek, zásob, zdrojů ... a jejich spotřeba

...a netradiční, nekonvenční zdroje, ... a perspektivy...

Římský klub a zdroje-suroviny

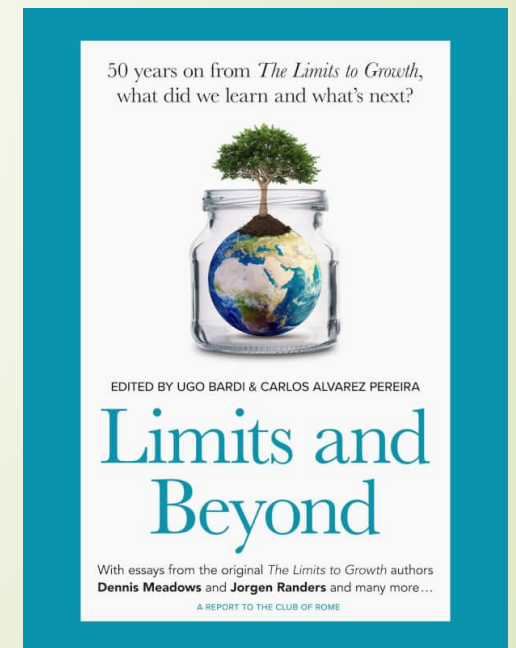


Organizace zvaná "Římský klub" v roce 1972 vyhlásila v knize "Meze růstu", že nám brzy prý **dojdou suroviny (ropa do 1992)**. ŘK prý nevěří, že je možný další růst a rozvoj. Nevěří, že najdeme nová řešení. Růst je prý neudržitelný a musí být zastaven cíleně, pozvolna a včas, jinak přijde kolaps náhle a prudce.

Navzdory tomu je podle Římského klubu cíl dosažení společenské renesance, která přinese více společenské rovnosti a upřednostní rovnováhu mezi člověkem a přírodou. Římský klub proto apeluje na vlády, manažery, vědce, nevládní organizace i občany, aby začali brát hrozbu změny klimatu vážně a vytvořili civilizaci, která bude **prosperovat s respektem k planetárním mezím**.

...Do roku 2020 zajistit exponenciální rozvoj technologií. Do roku 2025 **zabezpečit vyšší efektivitu využívání materiálů a surovin a jejich recyklaci**. Rozšířit nízkouhlíkové využívání půdy a nástroje, jak snižovat emise skleníkových plynů, a přizpůsobovat se dopadům změny klimatu (mitigační a adaptační opatření)....

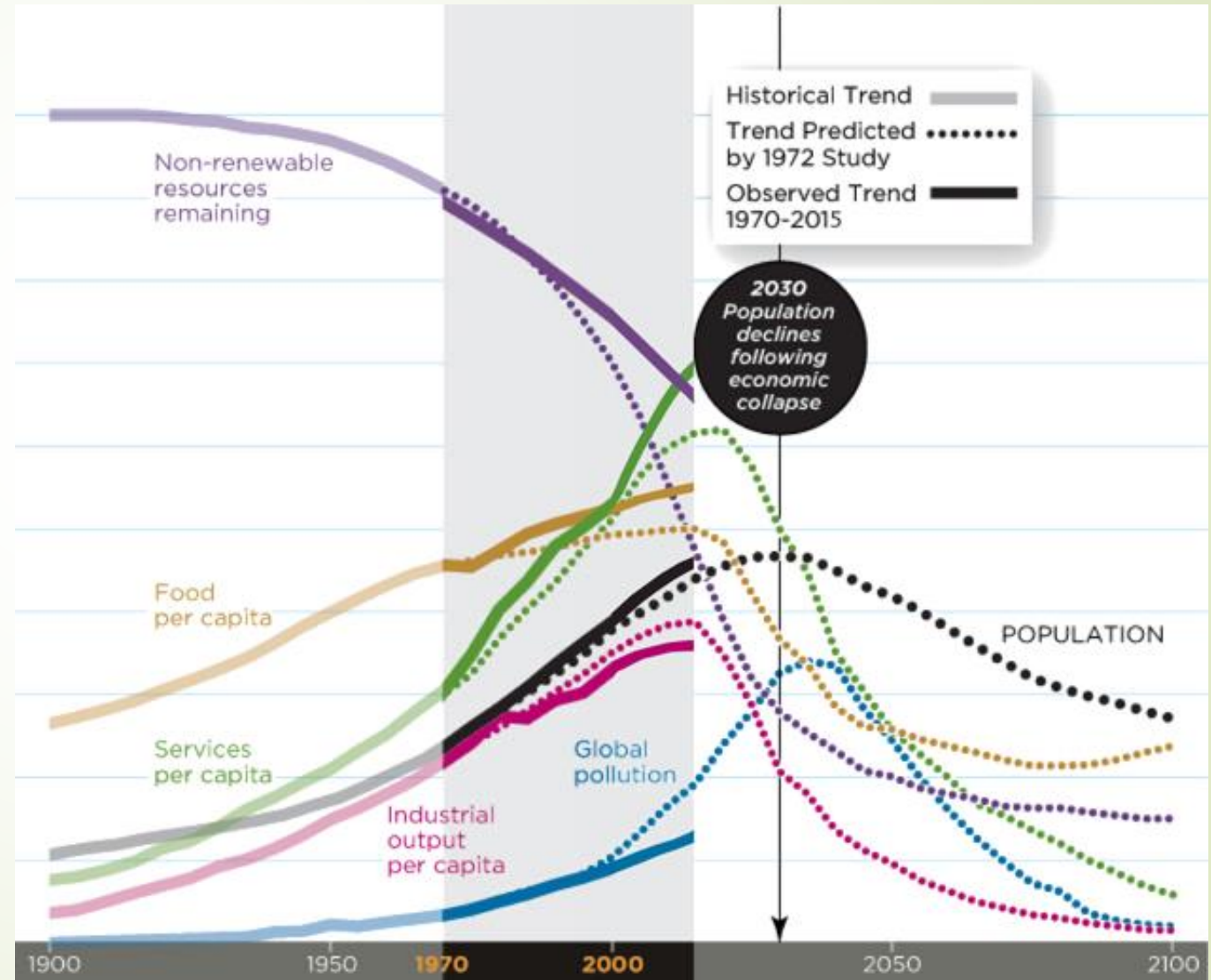
Limits and Beyond: 50 years on from The Limits to Growth, what did we learn and what's next?



...is it bleak...? (bezútěšný)

Yep, it's bleak, says expert who tested 1970s end-of-the-world prediction (Sun 25 Jul 2021 16.00 AEST)

<https://wattsupwiththat.com/2021/07/26/guardian-2040-club-of-rome-end-of-world-prediction-on-track-thanks-to-climate-change/>



Josef Šmajš: Biofilní desatero



Profesor Ekonomicko-správní fakulty MU Josef Šmajš (1938) se již řadu let zabývá konfliktem lidské civilizace (v jeho pojetí kultury) a přírody. Vytvořil koncept evoluční ontologie, který rozpracoval ve svých knihách *Ohrožená kultura* (1995, 1997, 2011), *Evoluční ontologie* (2003), *Filosofie – obrat k Zemi* (2008) či *Potřebujeme filosofii přežití?* (2011).

„...naše **predátorská kultura** už téměř jedno století vede krutou nevyhlášenou válku se Zemí, druhový existenční zápas se širším a mocnějším přírodním systémem, který bez radikální změny své strategie nemůže vyhrát“

Globální kultura, kdysi nastavená nejen lidským genomem, ale později v Řecku i skrytým predátorským duchovním paradigmatem, dospěla do stádia svého možného zániku. Všem známý kopernikánský objev Země jen jako planety obíhající kolem Slunce bledne před zjištěním, že lidstvo si neúctou k přírodě může zkrátit biologicky vymezenou dobu své druhové existence. Bez biofilního obratu, tj. vůči přírodě vstřícnému poznání, aktivitě a materiální kultuře, hrozí lidstvu **vyhynutí z jeho vlastní intelektuální omezenosti**. Smyslem biofilního desatera je připomenout pravdu o místě člověka a kultury v přírodě.

1. Člověče, uctívej Zemi, svébytný planetární systém, jehož přirozená evoluce tě zrodila.
2. Pomni, že jako dočasně existující druh nejsi skutečným partnerem Země, ale jen domýšlivým soupeřem její velkolepé tvořivé schopnosti.
3. Závisíš na Zemi každým nadechnutím, každým douškem vody, každým soustem.
4. Jsi postaven z chemických prvků Země, které, až umřeš, si planeta vezme zpět.
5. Země ti nepatří, i když se ti na čas podařilo zapálit opoziční kulturní evoluci.
6. Kultura ti rovněž nenáleží, neboť ji buduješ z přírodě odcizené látky, energie a informace, tvoříš ji na úkor úbytku přirozené uspořádanosti planety.
7. Kulturní evolucí vytváříš uměle uspořádanou stavbu, ale jen jako chatrč ze sutin boženého chrámu důmyslného kosmického výtvaru Země.
8. Tvoje protipřírodně orientovaná kultura je sice tvou druhovou pýchou, ale ubližuje nejen Zemi, nýbrž i tobě, jsi ohroženým druhem.
9. Pomni, že Země kulturu nepotřebuje a že její novátorství nemůže přijmout; po tvém zániku se ani nejdůmyslnější teorie a technické systémy na Zemi nezachovají.
10. Člověče, respektuj starší, širší a mocnější síly planety, pečuj o její nadřazenou subjektivitu, již je tvá vzdorovitá subjektivita jen částí a příběhem.

Životnost surovin

...odvíjí se od investic do průzkumu, **výzkumu** a dalších faktorů:
např. scénáře A, B, C

Jak působí technologický pokrok a čím je sám ovlivňován?

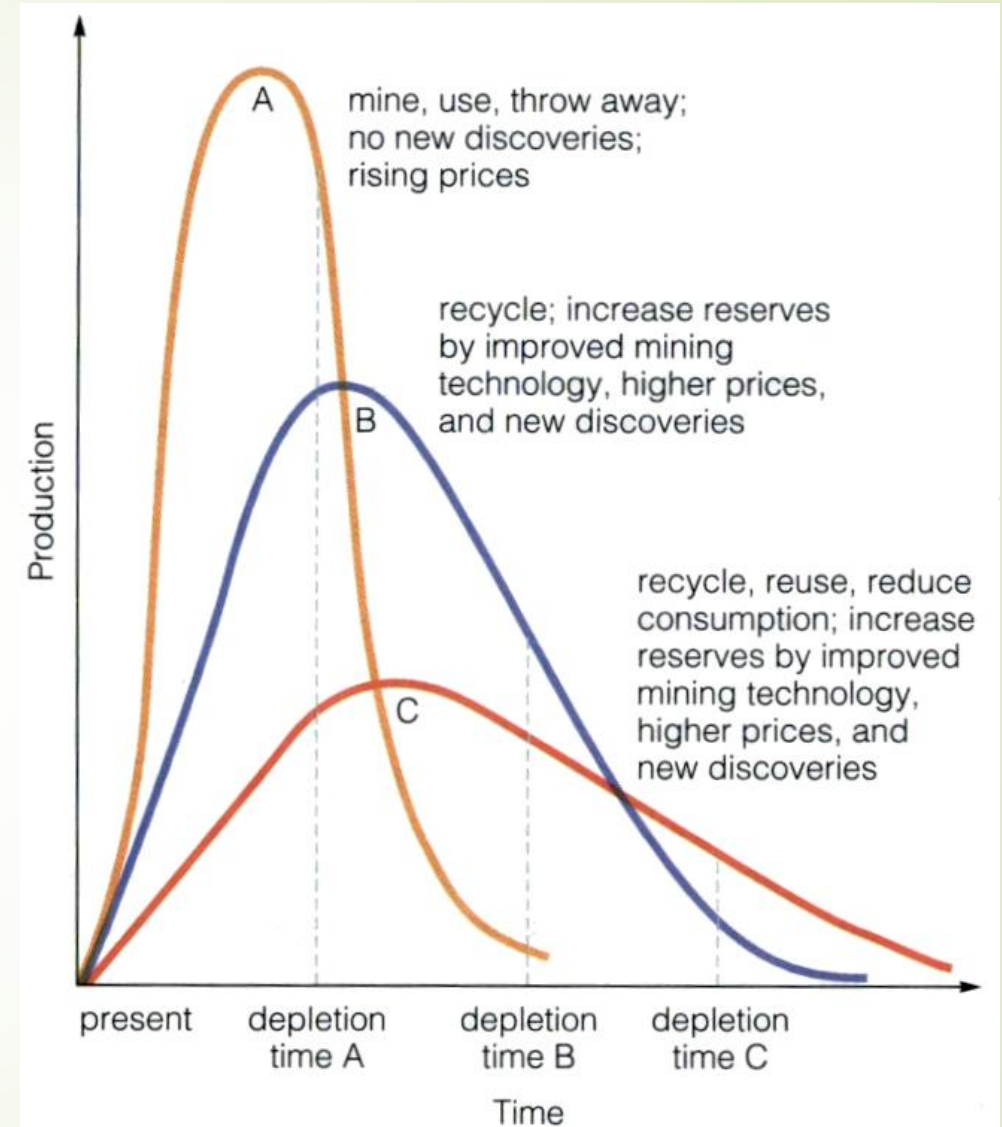


Figure 12-13 Depletion curves for a nonrenewable resource (such as aluminum or copper) using three sets of assumptions. Vertical lines represent times when 80% depletion occurs.

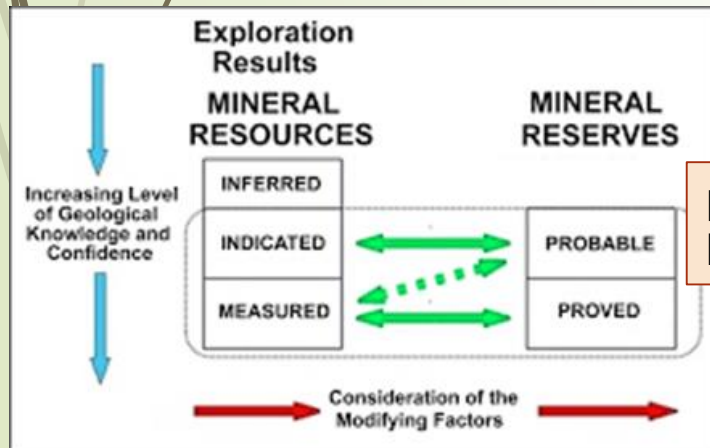
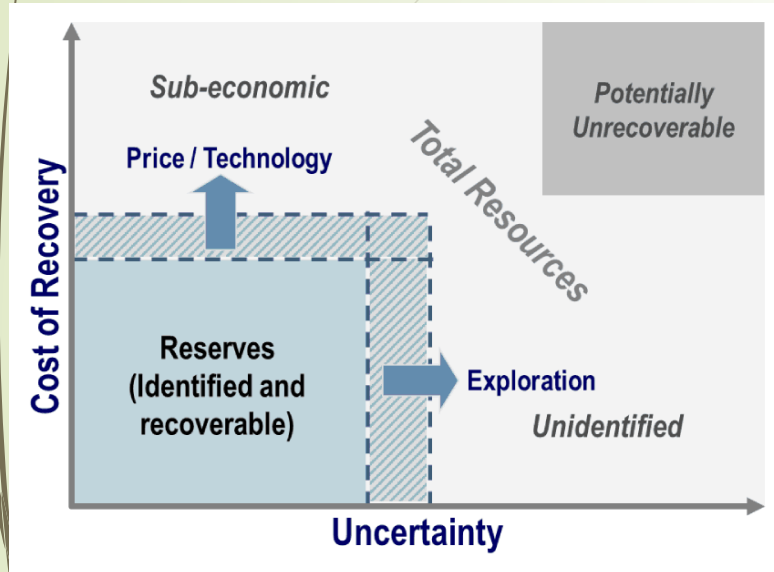
Zásoby a spotřeba surovin

Zásoby a spotřeba surovin jsou neoddělitelné kategorie, které je nutno posuzovat ve vzájemném propojení a v závislosti na času. V podstatě souvisejí s:

- cena surovin
 - poptávka
 - technický/technologický pokrok
 - investice do průzkumu
- prices
 - demand
 - progress
 - investments

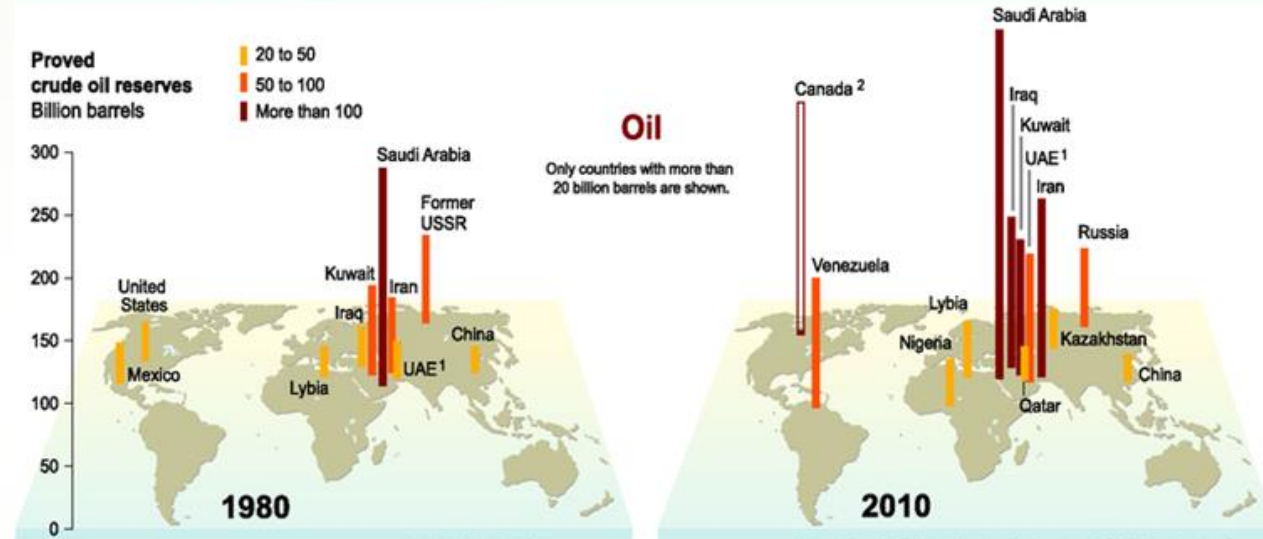
Quantity of reserves changes in time!!!

Zásoby a spotřeba – dynamické kategorie



pohyb i mezi kategoriemi

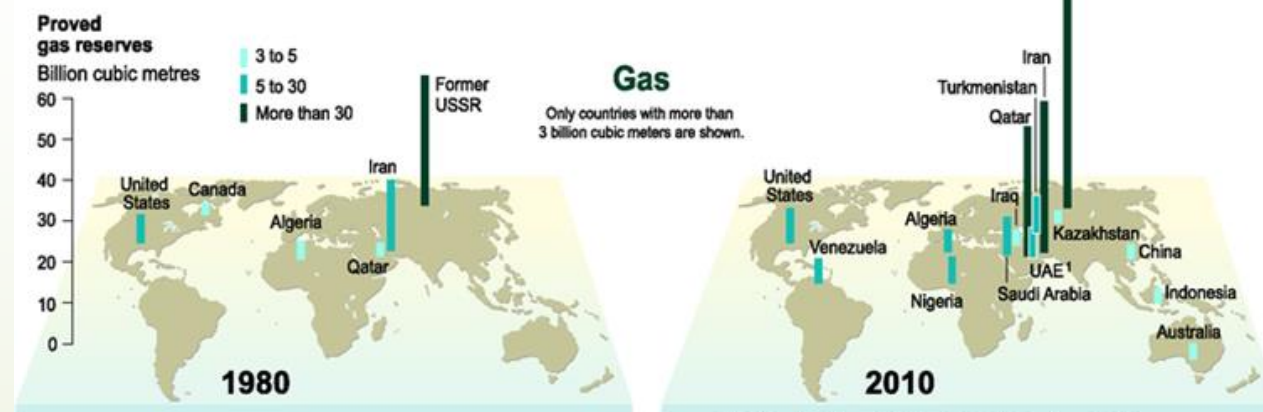
Selected oil and gas reserves



1 - United Arab Emirates.

2 - Including 172.3 billion barrels of oil sands and 5.2 billion barrels of conventional oil and condensate.

The countries represented here hold stocks of 80% of global proved reserves.

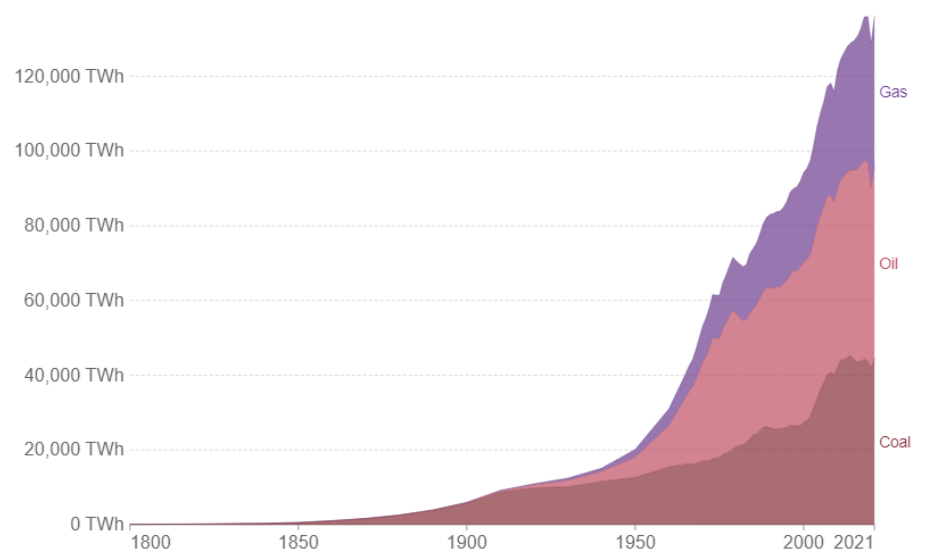


Sources: EIA, International Energy Statistics, 2010; Oil & Gas Journal, 2010.

Spotřeba energie

Global fossil fuel consumption

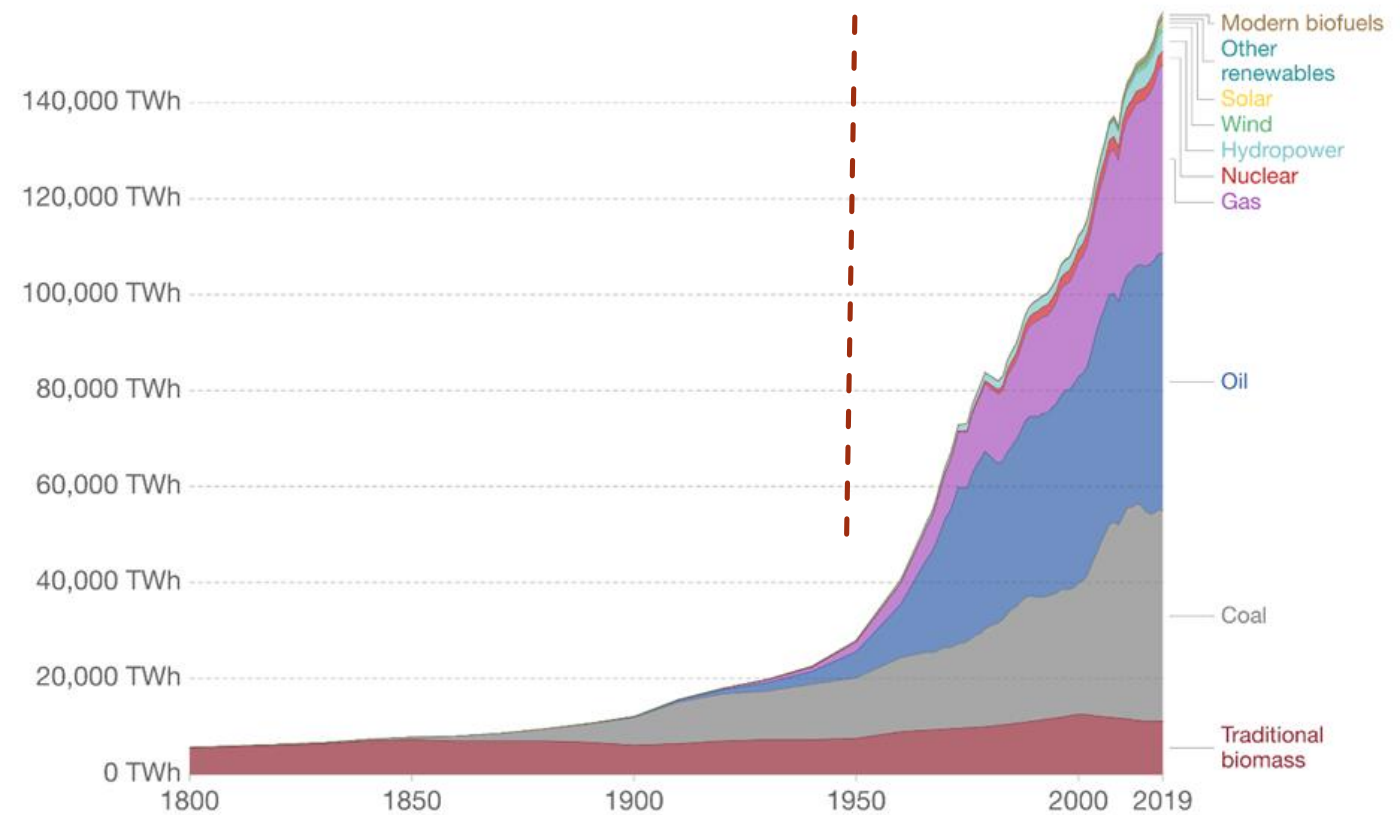
Global primary energy consumption by fossil fuel source, measured in terawatt-hours (TWh).



Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy OurWorldInData.org/fossil-fuels/ • CC BY

Global direct primary energy consumption

Direct primary energy consumption does not take account of inefficiencies in fossil fuel production.

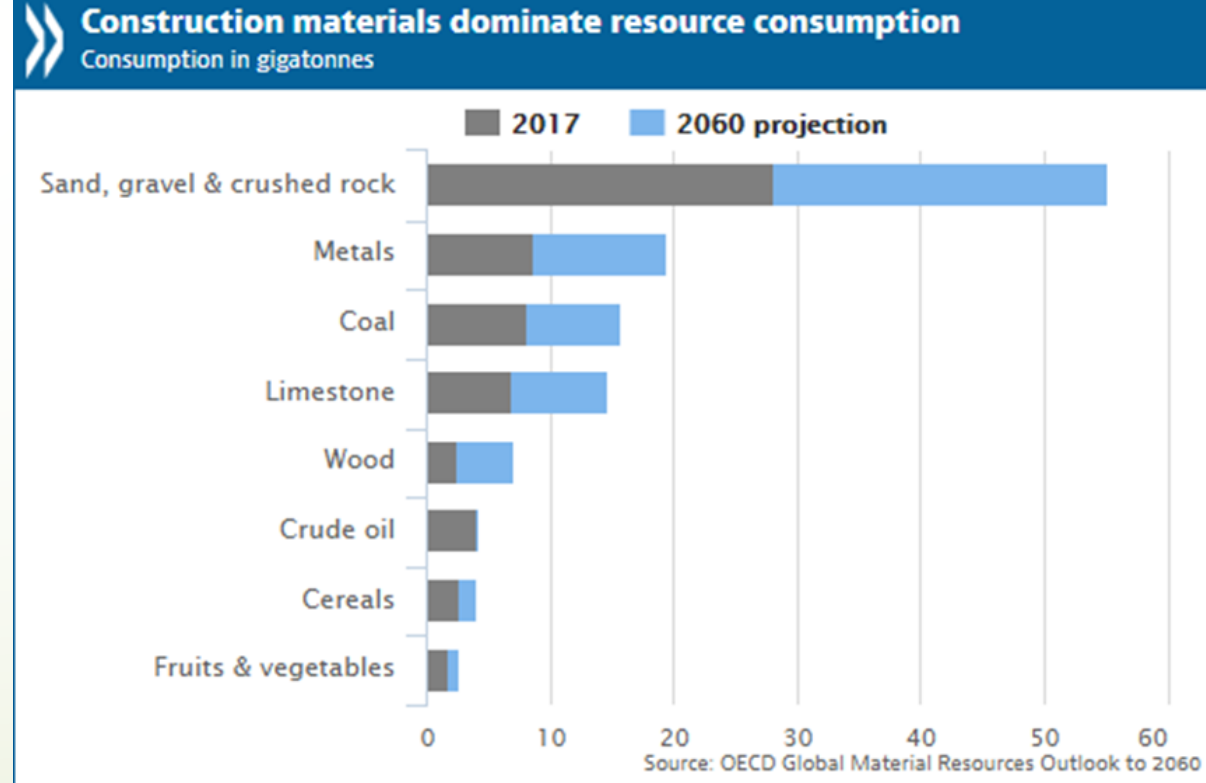
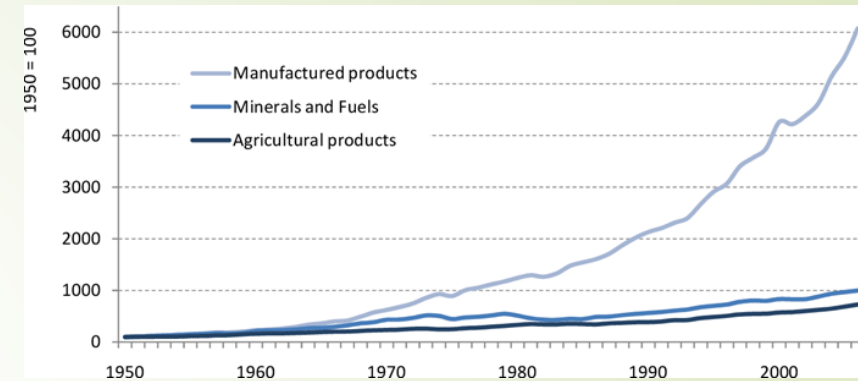
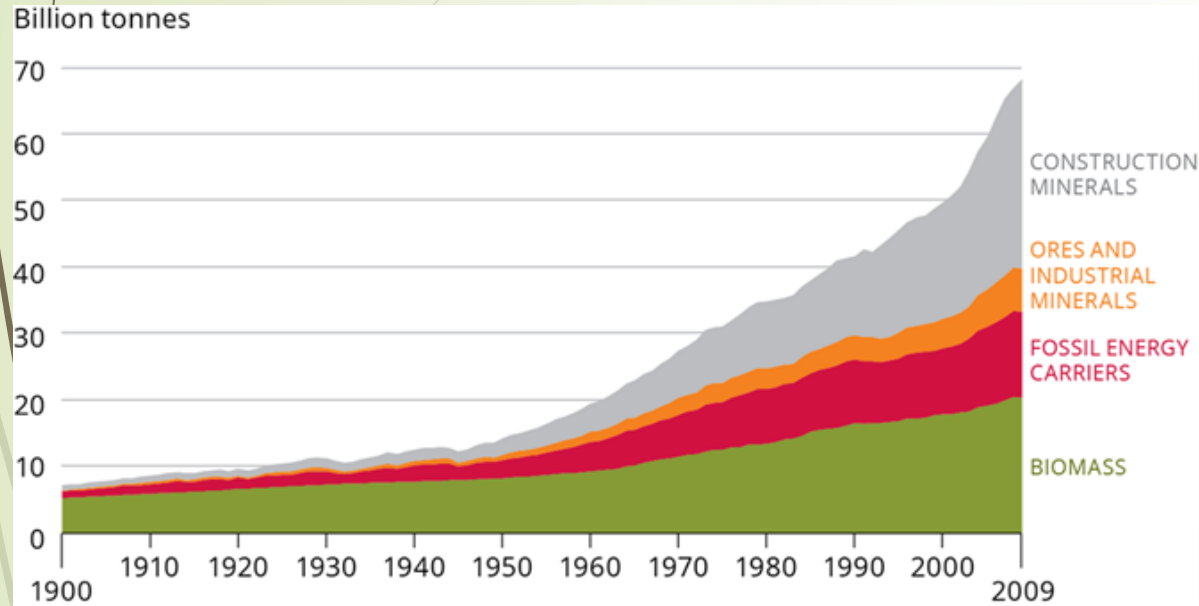


Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

OurWorldInData.org/energy/ • CC BY

Spotřeba surovin - svět

Giljum et al. 2009



Světová těžba surovin

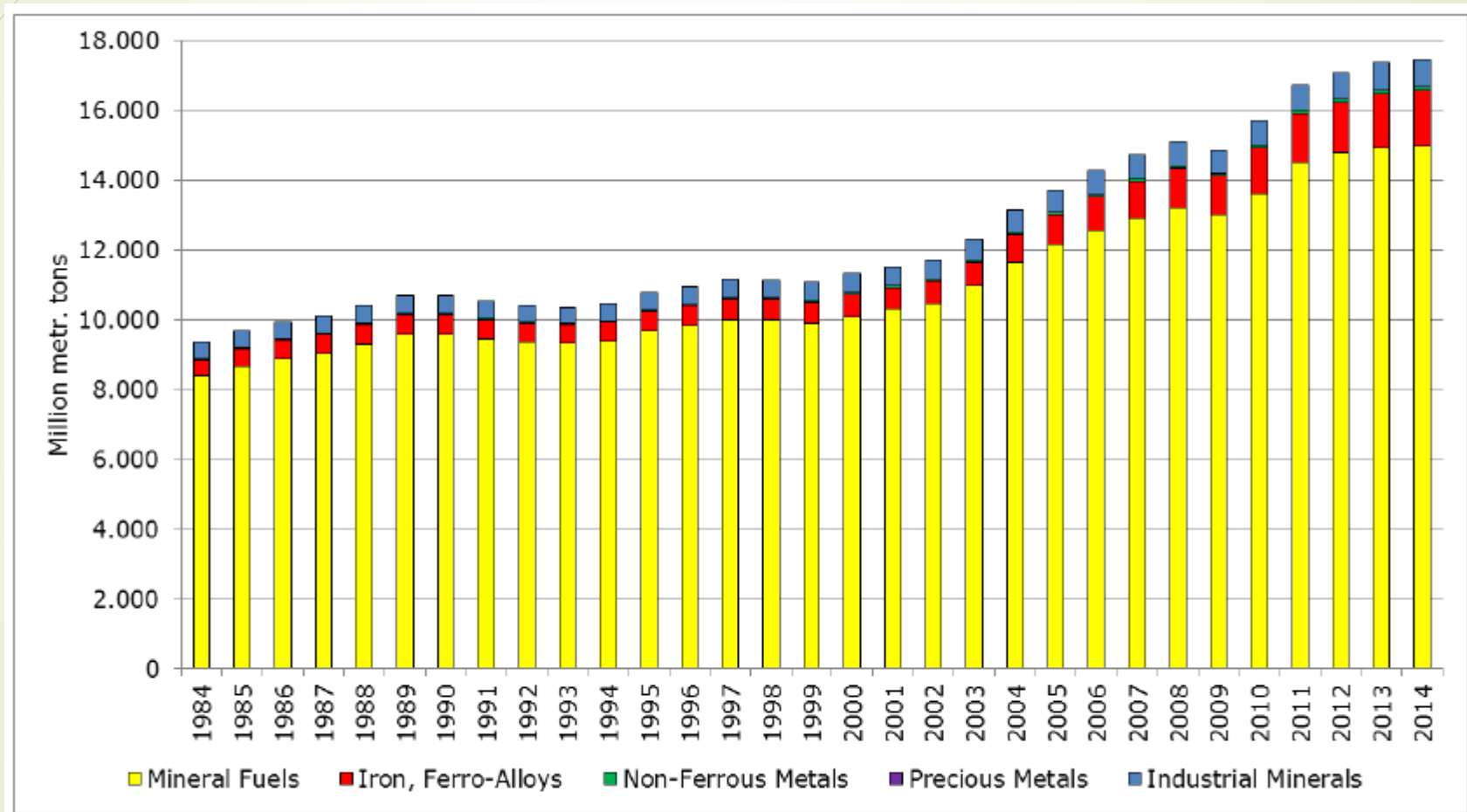
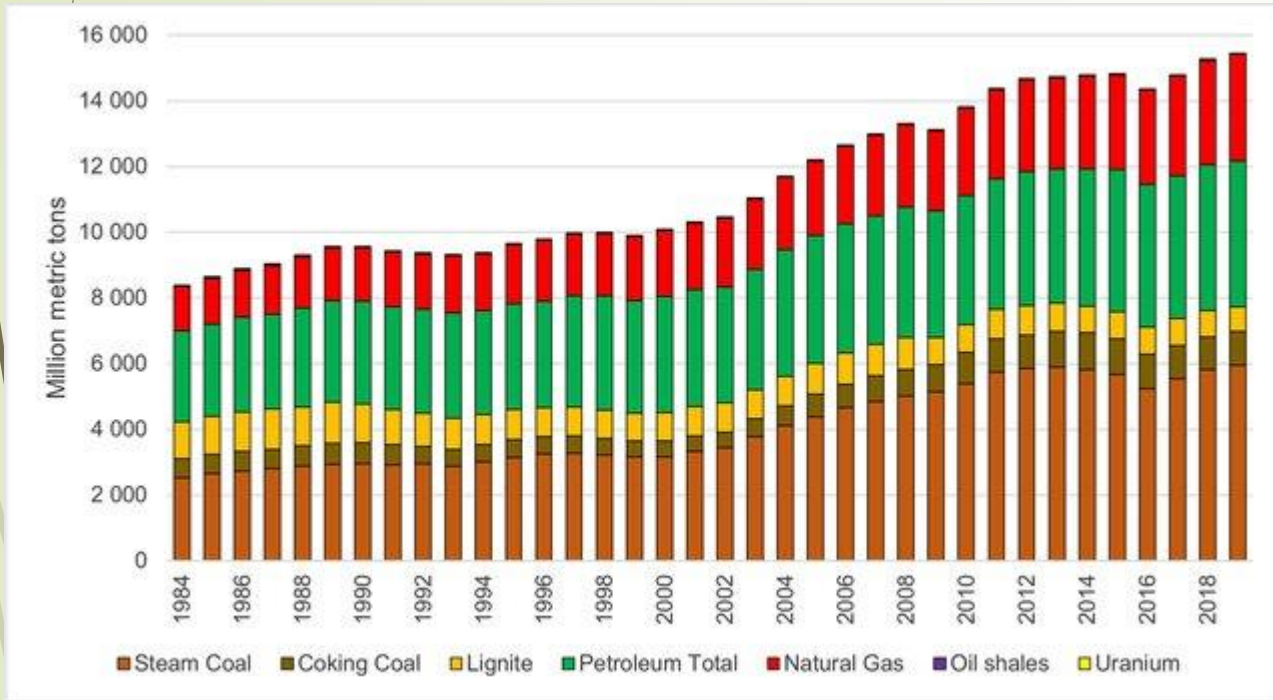


Fig. 1: World mining production 1984 - 2014 by groups of minerals (without construction minerals, in Million metr. t)

Světová těžba energetických surovin

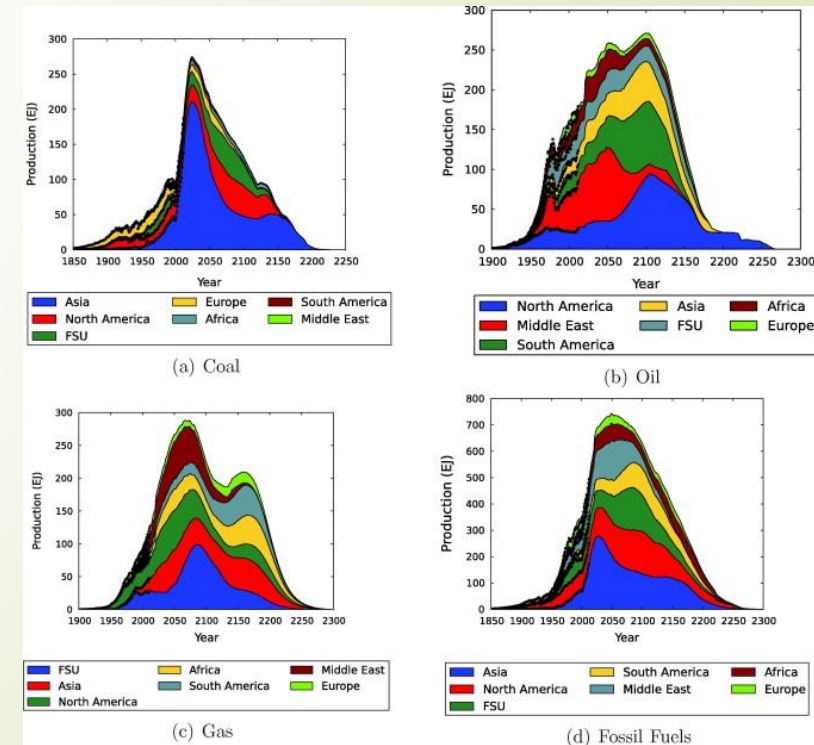
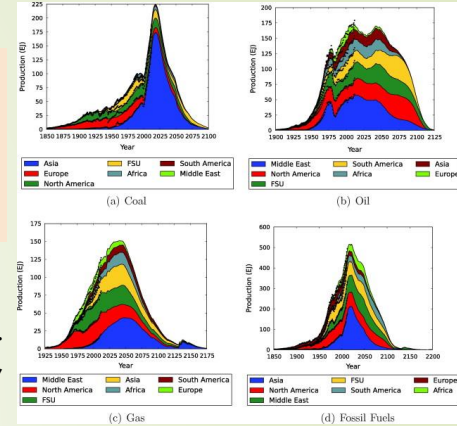


World mining production of energy fuels in Mio metr. † (source WORLD MINING DATA 2021).
 Conversion factor for natural gas (approximate method): 1 m³ = 0.8 kg = 0.0008 metr. †

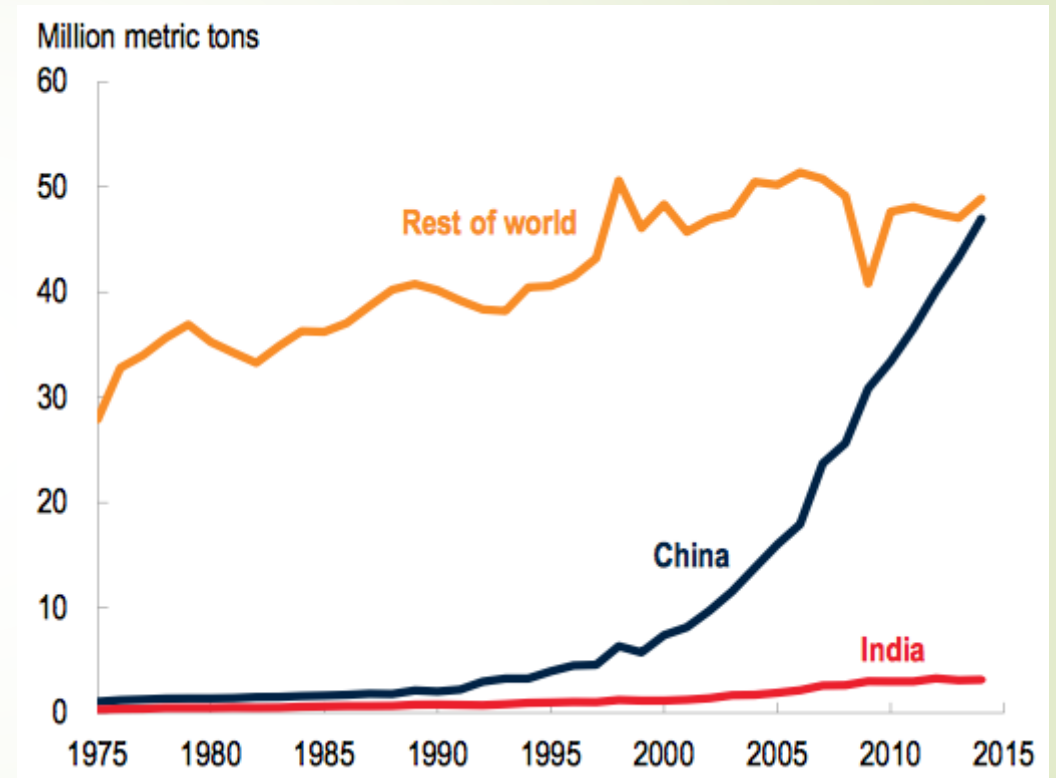
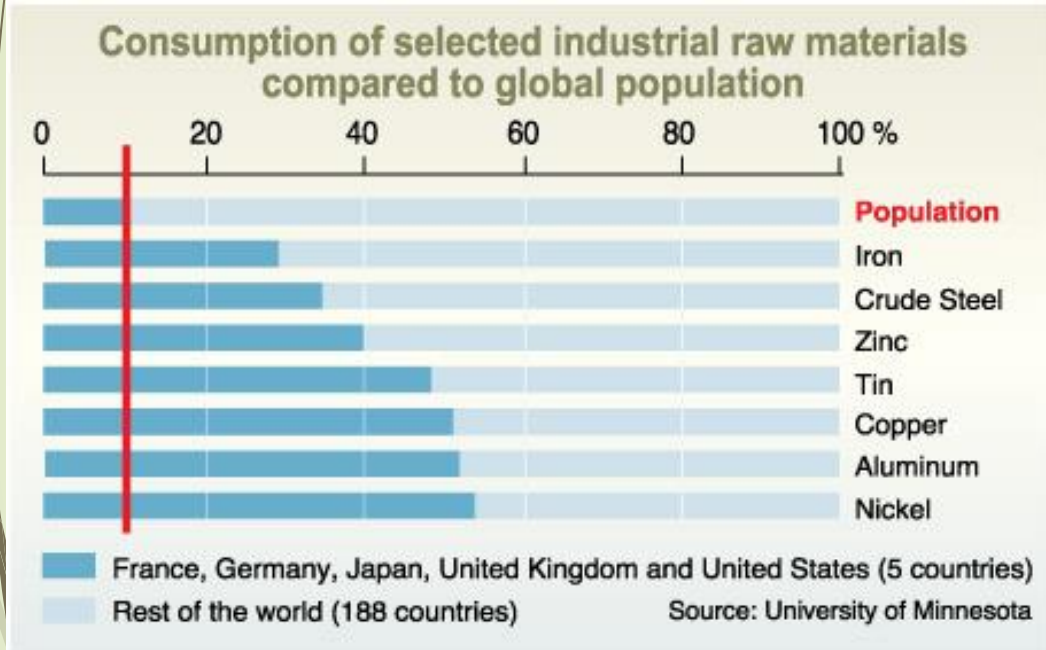
Mineral statistics—useful tool or needless exercise?
 Springer
 April 2022 Mineral Economics 35(3-4)
 DOI: 10.1007/s13563-022-00314-6
 Leopold Weber Christian Reichl

Modely těžby: Low and high scenarios results by fossil fuel

S.H. Mohr, J. Wang, G. Ellem, J. Ward, D. Giurco (2015). Projection of world fossil fuels by country. Fuel, Volume 141, 2015, 120-135. ISSN 0016-2361, <https://doi.org/10.1016/j.fuel.2014.10.030>.



Spotřeba nerostných surovin



China's share of world **metals** consumption tripled from 13 percent in 2000 to 47 percent in **2014**.

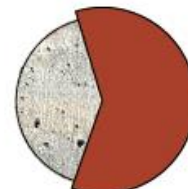
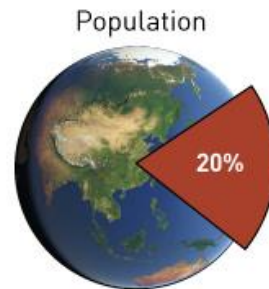
Čína – spotřeba surovin

Published 7 years ago on
September 10, 2015
By Jeff Desjardins

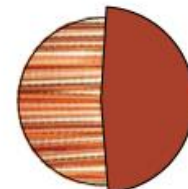
Chart of the Week

CHINA CONSUMES MIND-BOGGLING AMOUNTS OF RAW MATERIALS

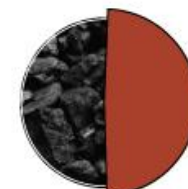
...and that's why slowing growth may continue to cause headaches for commodity producers



Concrete
60%



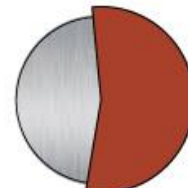
Copper
48%



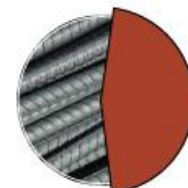
Coal
49%



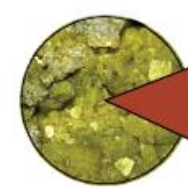
Rice
30%



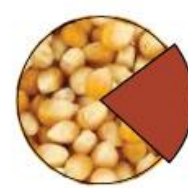
Aluminum
54%



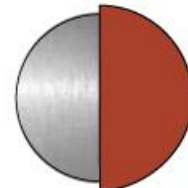
Steel
46%



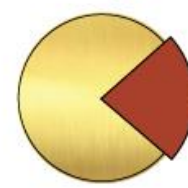
Uranium
13%



Corn
22%



Nickel
50%



Gold
23%



Oil
12%



Wheat
17%



Nerostné zdroje EU a jejich zajištění

Raw Materials Initiative

Dne 4. 11. 2008 uveřejňuje Evropská komise v rámci COM (2008) 699 COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL nazvanou „**THE RAW MATERIALS INITIATIVE** — MEETING OUR CRITICAL NEEDS FOR GROWTH AND JOBS IN EUROPE“

(http://www.euromines.org/who_is_downloads/raw_materials_initiative.pdf)

Je založena na naplňování 3 základní pilířů:

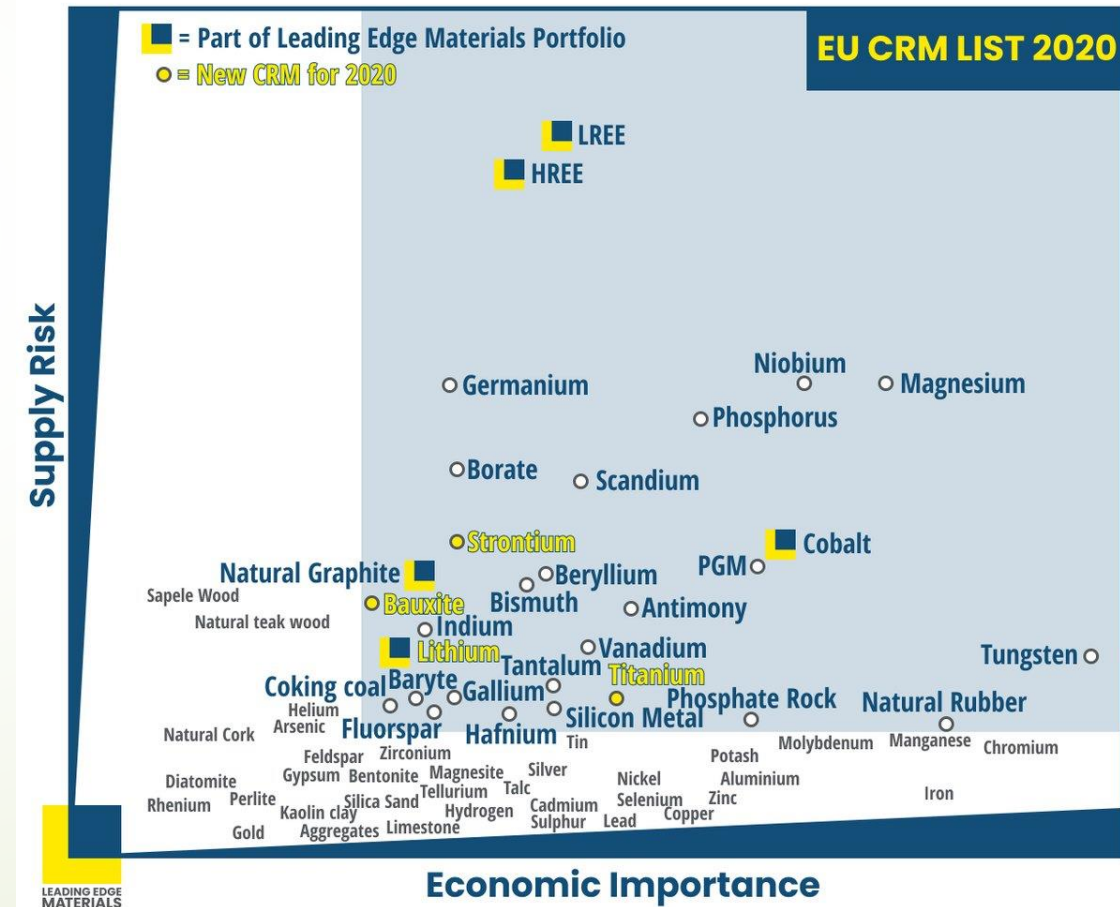
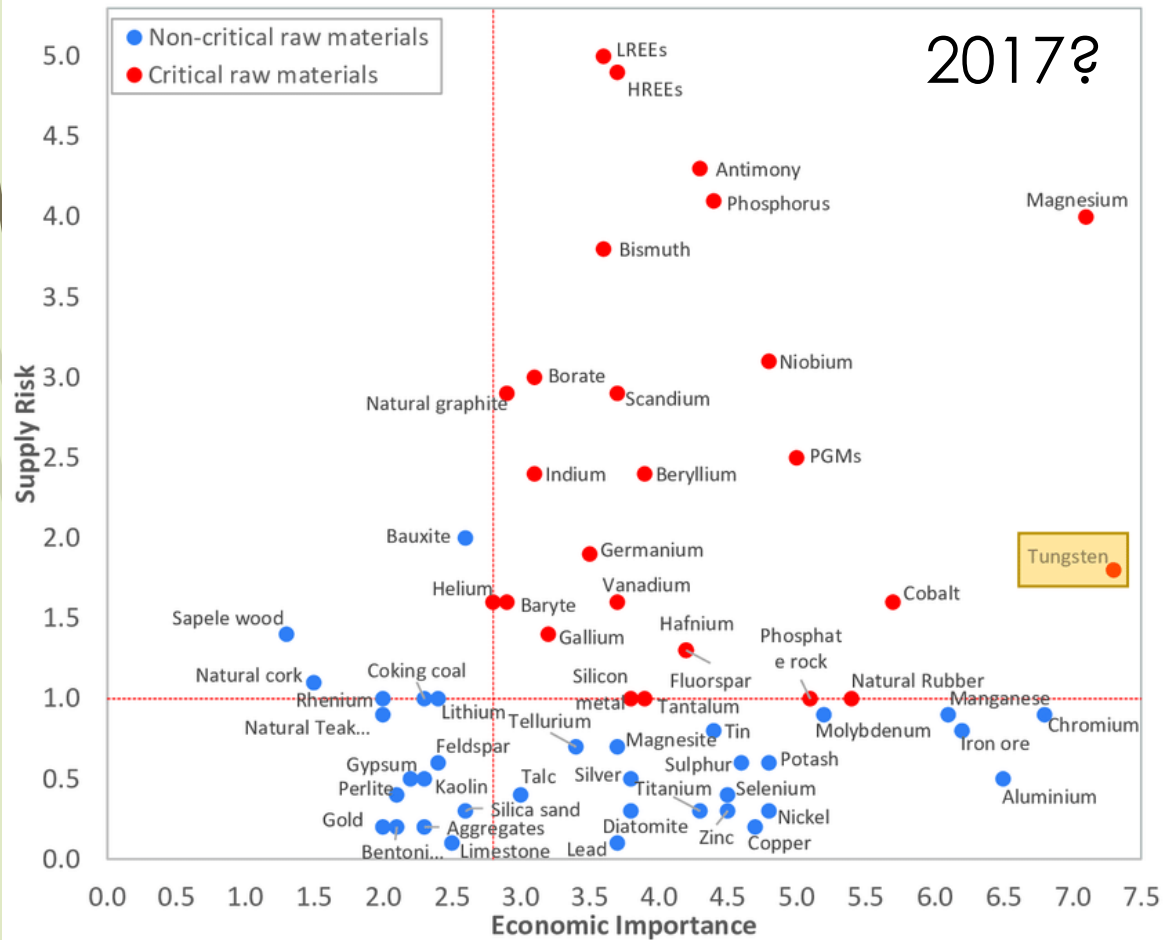
- 1) Access to raw materials on world markets at undistorted conditions**
- 2) Foster sustainable supply of raw materials from European sources**
- 3) Reduce the EU's consumption of primary raw materials**

Jako strategický dokument zavádí celou řadu prvků, které by měly být následně rozpracovány formou dílčích strategií či legislativních aktů (kupříkladu tzv. kritické suroviny, efektivita při využívání primárních surovin ad.)

přístup + podpora (starost) + redukce spotřeby

Critical raw materials

| 2020 critical raw materials (new as compared to 2017 in bold) | | |
|---|---------------------------|------------------|
| Antimony | Hafnium | Phosphorus |
| Baryte | Heavy Rare Earth Elements | Scandium |
| Beryllium | Light Rare Earth Elements | Silicon metal |
| Bismuth | Indium | Tantalum |
| Borate | Magnesium | Tungsten |
| Cobalt | Natural graphite | Vanadium |
| Coking coal | Natural rubber | Bauxite |
| Fluorspar | Niobium | Lithium |
| Gallium | Platinum Group Metals | Titanium |
| Germanium | Phosphate rock | Strontium |



Produkce kritických surovin (2014/2016)

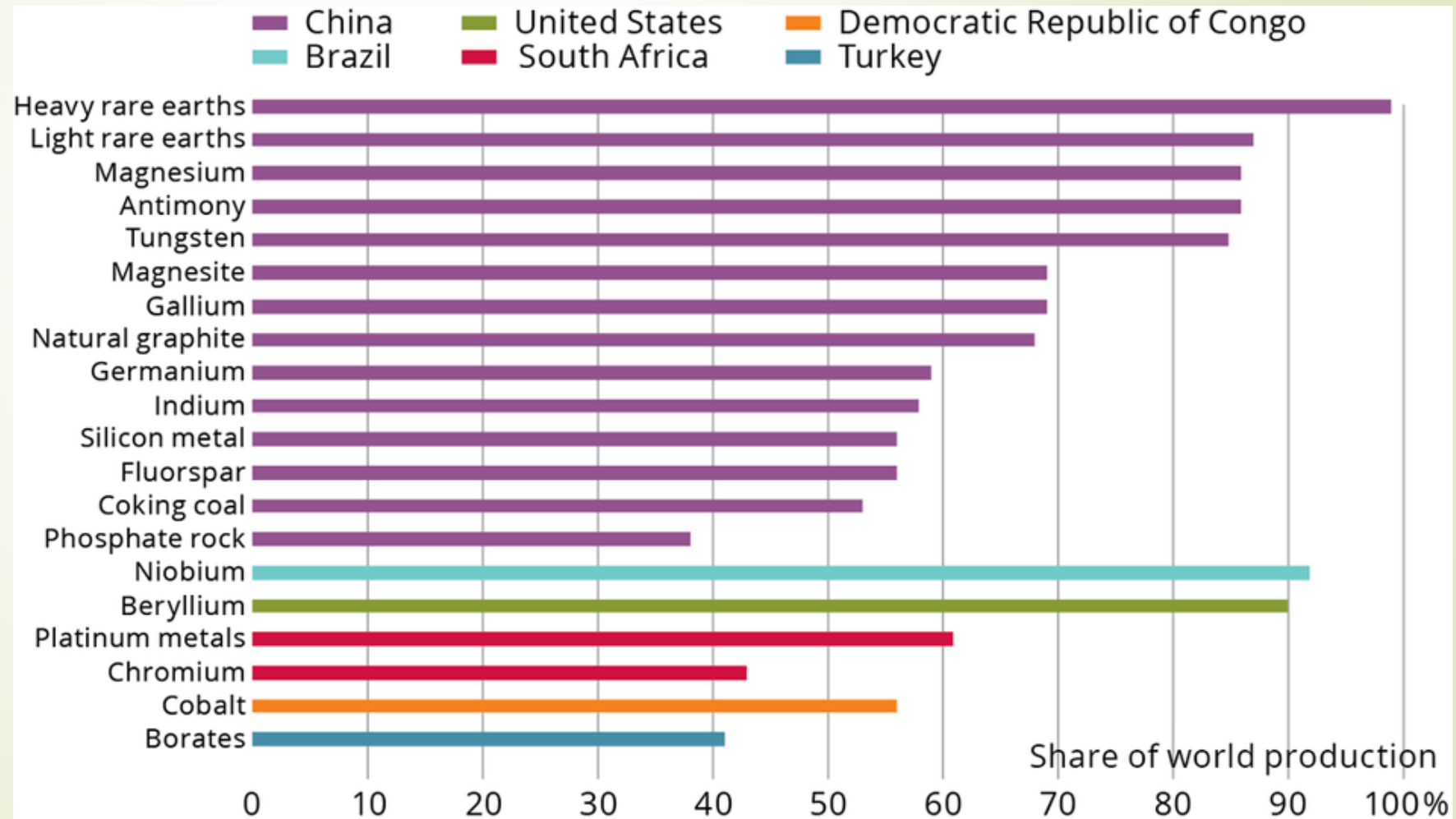
Percentage of global production of **EC critical raw materials** within a single country

Created 31 Oct 2014

Published 28 Feb 2015

Last modified 15 Jul 2016

The figure shows the 20 raw materials identified by the European Commission as being critical because risks of supply shortage and their impacts on the economy.



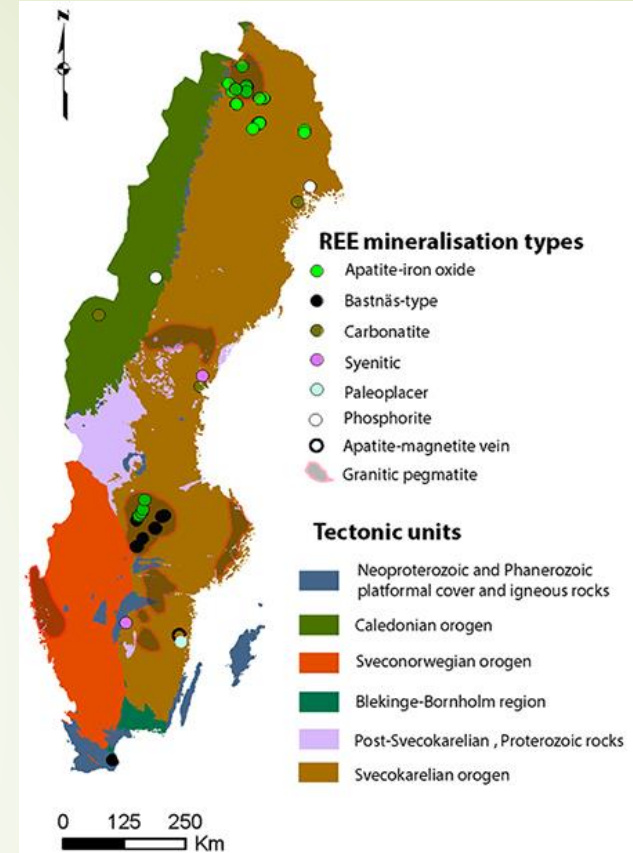
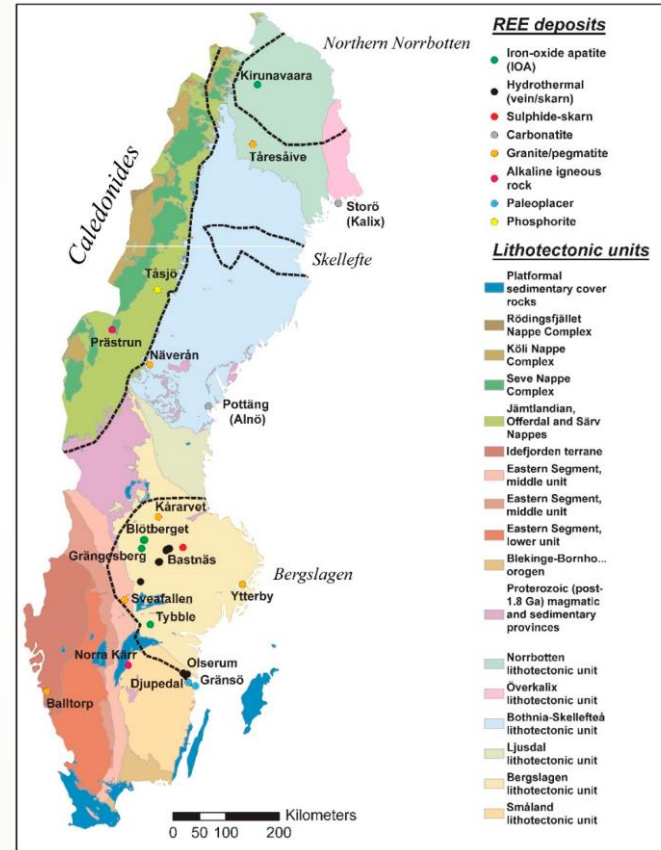
Nové ložisko REE ve Švédsku



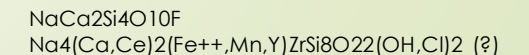
Železný důl švédské státní těžební společnosti LKAB v nejsevernějším švédském městě Kiruna, v jehož blízkosti bylo objeveno největší známé evropské ložisko prvků vzácných zemin.

The Per Geijer deposit, just north of the company's largest iron ore mine in the Swedish Arctic, is estimated to contain more than 1 million tonnes of rare earths, LKAB said.

Work is still in an exploratory phase, the miner noted, and the full extent of the deposit is not known.

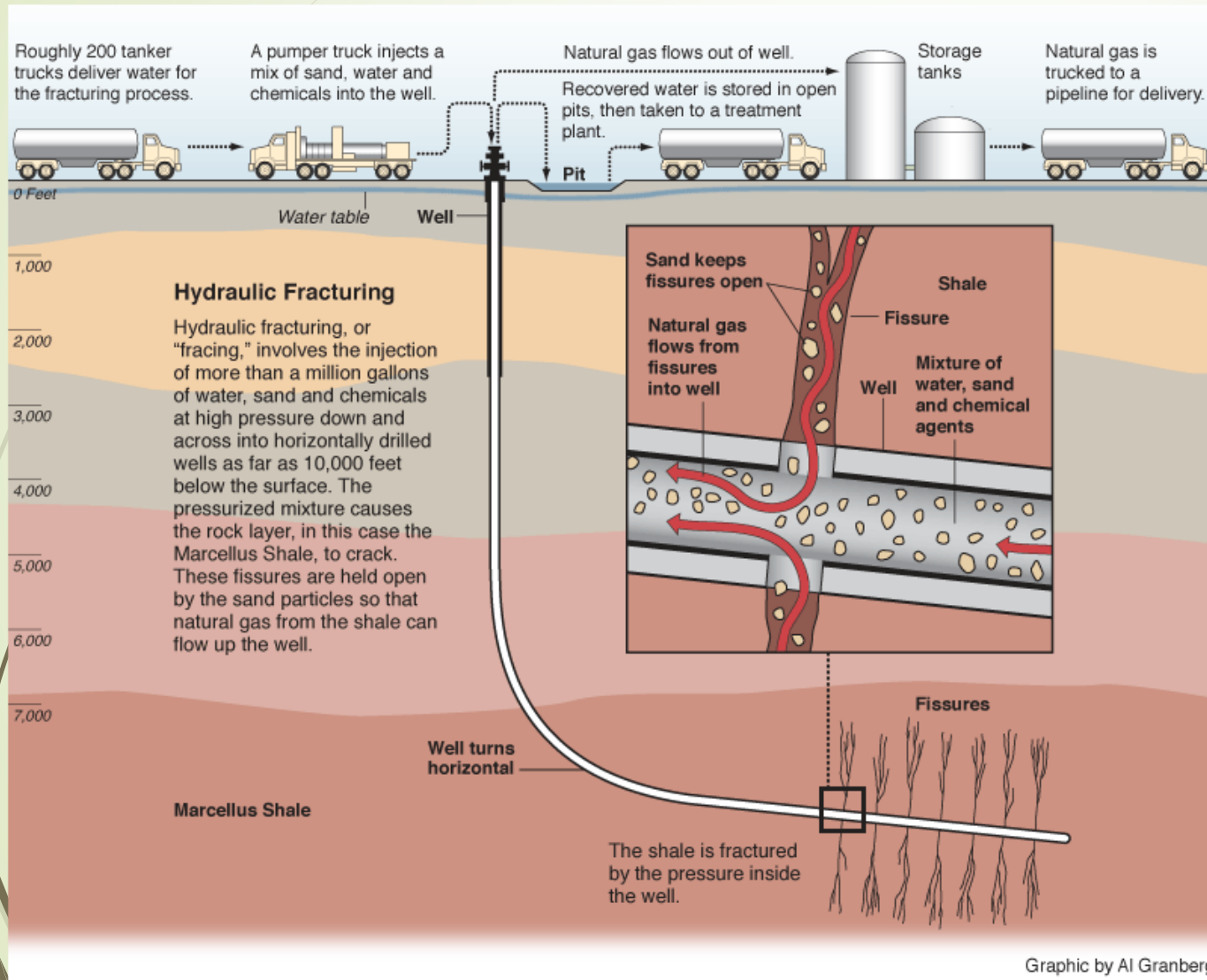


Tan agrellite grain, with red eudialyte.



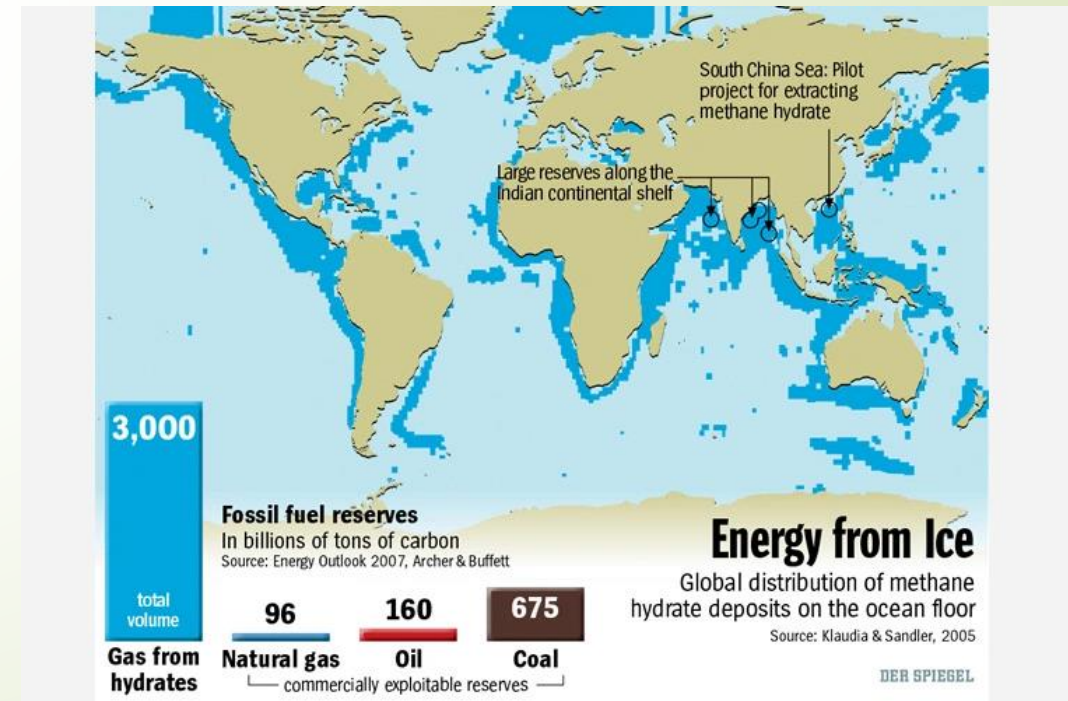
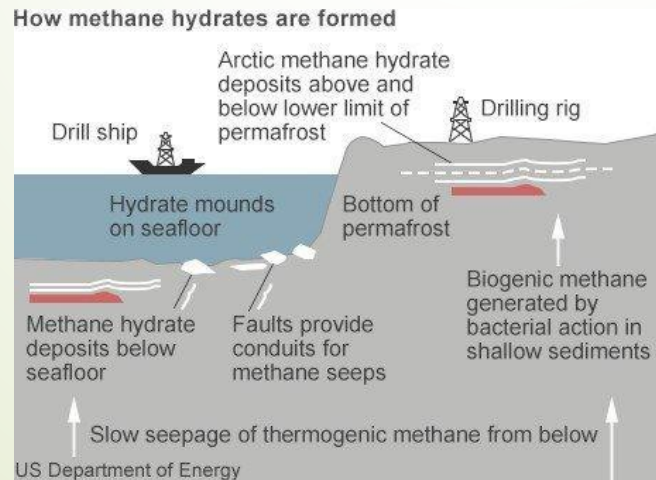
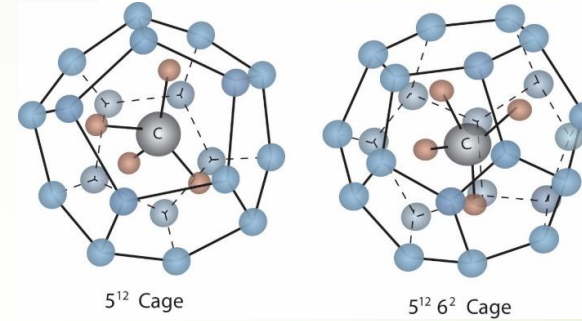
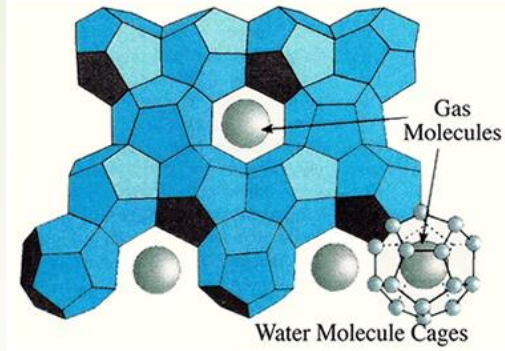
Těžba plynu z břidlic

... a dále několik dalších nekonvenčních ložisek...

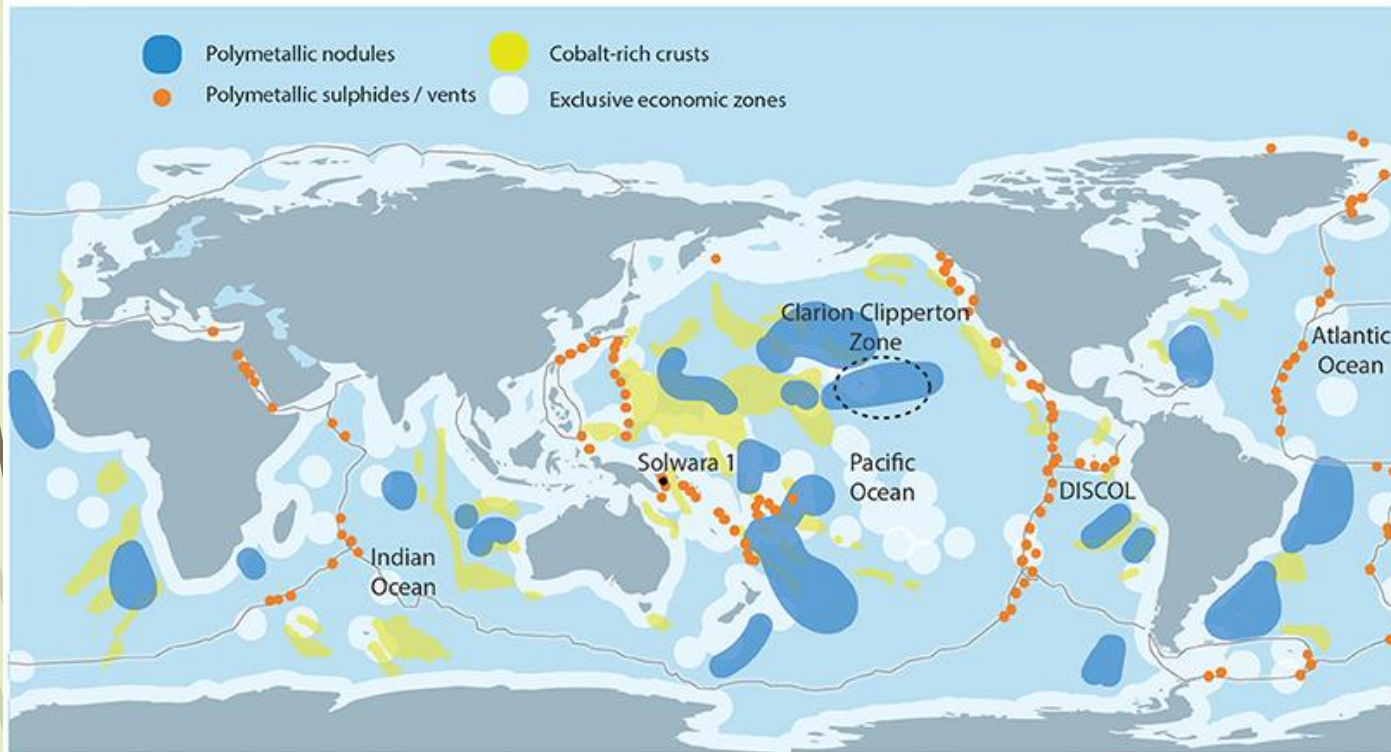


Environmental risks

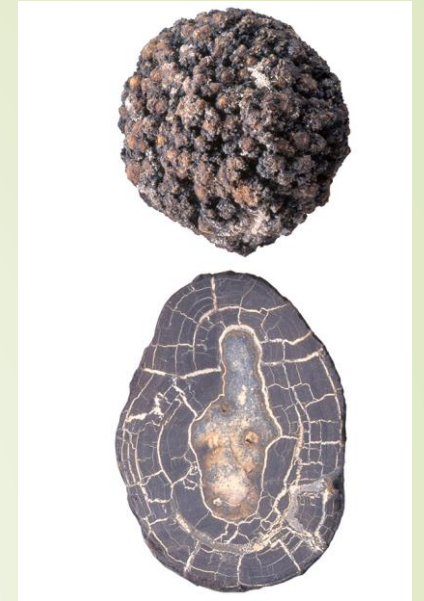
Hydráty metanu



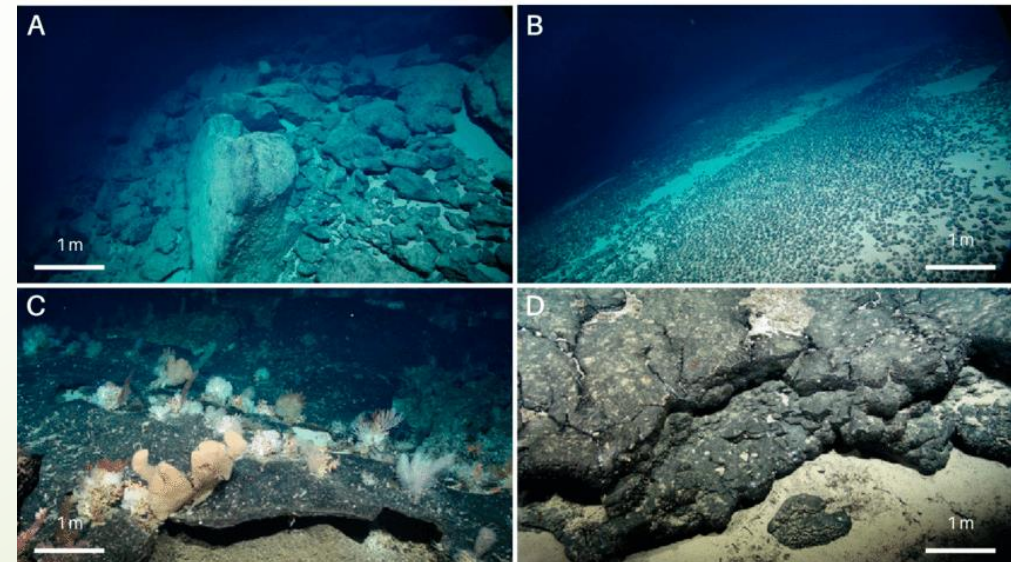
Fe-Mn konkrece/nodules



A world map showing the location of the three main marine mineral deposits: polymetallic nodules (blue); polymetallic or seafloor massive sulfides (orange); and cobalt-rich ferromanganese crusts (yellow). Redrawn from a number of sources including Hein et al. (2013).



Ferromanganese crusts and nodules on Tropic Seamount (Atlantic Ocean). A. Encrusted debris flow cobbles on the steep flanks of the seamount (depth 1450 metres). B. A nodule field in a sediment-rich area on the flank of the seamount (depth 3640 metres). C. Ferromanganese crust pavement covered by biological debris on a gentle slope on the seamount flank (depth 1600 metres). D. Massive ferromanganese crust partially covered in sediment (depth 3772 metres) (Lusty et al., 2018).



Fe-Mn nodules

| Chemical components of manganese nodules from different marine regions | | | | |
|--|------------------------------|-------------------------------------|---------------------------------------|--|
| Elements | Manganese nodules of the CCZ | Manganese nodules of the Peru Basin | Manganese nodules of the Indian Ocean | Manganese nodules of the Cook Islands area |
| Manganese (Mn) ** | 28.4 | 34.2 | 24.4 | 16.1 |
| Iron (Fe) ** | 6.16 | 6.12 | 7.14 | 16.1 |
| Copper (Cu) * | 10,714 | 5988 | 10,406 | 2268 |
| Nickel (Ni) * | 13,002 | 13,008 | 11,010 | 3827 |
| Cobalt (Co) * | 2098 | 475 | 1111 | 4124 |
| Titanium (Ti) ** | 0.32 | 0.16 | 0.42 | 1.15 |
| Tellurium (Te) * | 3.6 | 1.7 | 40 | 23 |
| Thallium (Tl) * | 199 | 129 | 347 | 138 |
| Rare earth elements and yttrium * | 813 | 403 | 1039 | 1707 |
| Zirconium (Zr) * | 307 | 325 | 752 | 588 |

Chemical analyses reveal that manganese nodules from different marine regions vary significantly in their metal contents.

* Grams per tonne

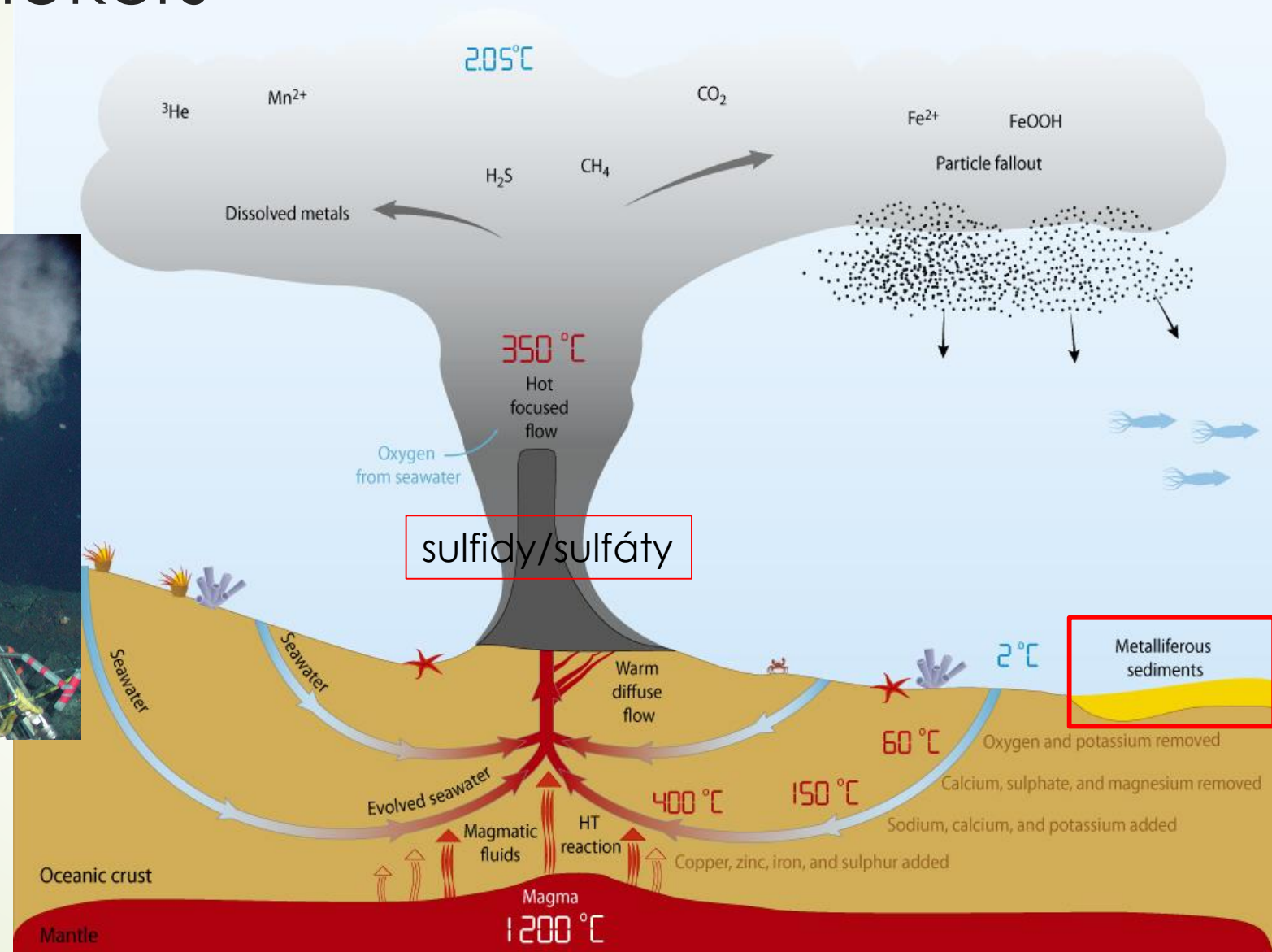
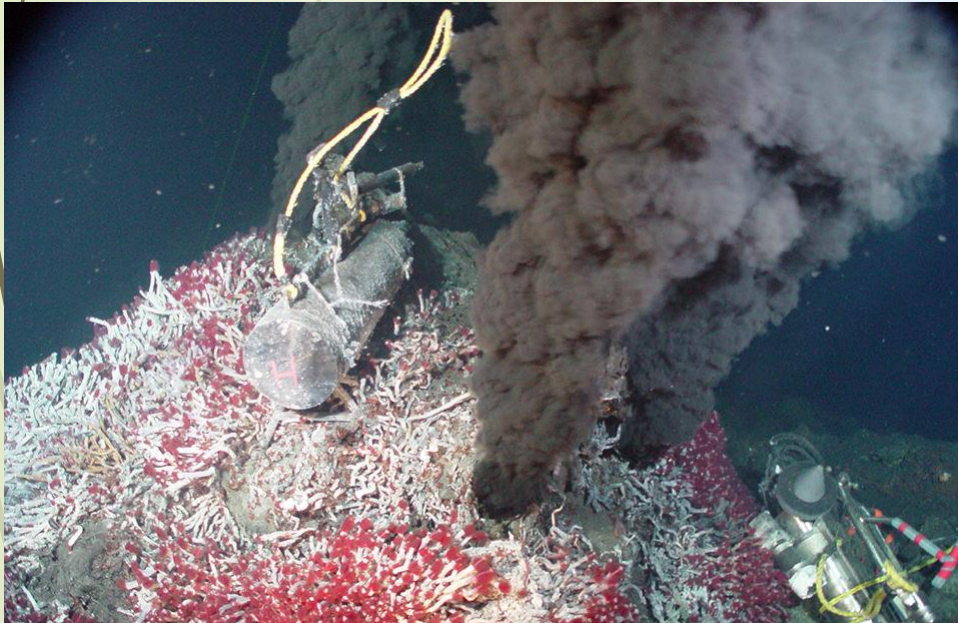
** Percentage by weight

| Element | World (<i>n</i> ≈ 2300) <i>d</i> ≈ 4270 m | Pacific (<i>n</i> ≈ 1700) <i>d</i> ≈ 4380 m | Indian (<i>n</i> ≈ 300) <i>d</i> ≈ 4300 m | Atlantic (<i>n</i> ≈ 300) <i>d</i> ≈ 3610 m | This study* (<i>n</i> = 3) <i>d</i> ≈ 5250 m |
|---------|--|--|--|--|---|
| Mn% | 18.6 | 20.1 | 15.3 | 13.2 | 12.4 |
| Fe% | 12.5 | 11.4 | 14.2 | 17.0 | 15.8 |
| Ni% | 0.66 | 0.76 | 0.43 | 0.32 | 0.33 |
| Cu% | 0.45 | 0.54 | 0.25 | 0.13 | 0.19 |
| Co% | 0.27 | 0.27 | 0.21 | 0.27 | 0.34 |
| Zn ppm | 1200 | 1160 | 1490 | 1230 | 610 |
| V ppm | 520 | 510 | 540 | 600 | 650 |
| Cr ppm | 70 | 90 | 20 | 60 | 40 |
| Mo ppm | 380 | 410 | 290 | 310 | 240 |
| Ba ppm | 2300 | 2350 | 2100 | 2280 | 1100 |
| P ppm | 3700 | 2800 | 3700 | 9100 | 3300 |
| Pb ppm | 930 | 830 | 1010 | 1400 | 1100 |
| As ppm | 140 | 110 | 180 | 200 | 230 |
| Cd ppm | 10 | 10 | 10 | 10 | 11 |
| Si% | 7.69 | 7.62 | 9.39 | 6.34 | – |
| Al% | 2.70 | 2.75 | 2.67 | 2.37 | 2.90 |
| Mg% | 1.57 | 1.50 | 1.43 | 1.86 | 1.20 |
| Na% | 1.97 | 2.05 | 1.70 | 1.86 | 0.92 |
| K% | 0.73 | 0.82 | 0.48 | 0.57 | 0.45 |
| Ca% | 2.23 | 1.96 | 1.97 | 3.72 | 1.27 |
| Ti% | 0.69 | 0.73 | 0.62 | 0.42 | 0.72 |
| S% | 0.51 | 0.32 | 0.83 | 1.34 | 0.16 |
| Sr ppm | 850 | 840 | 790 | 940 | 770 |
| Y ppm | 150 | 150 | 110 | 240 | 227 |
| Zr ppm | 570 | 610 | 340 | 560 | (400) |
| Nb ppm | 70 | 70 | 70 | 40 | – |
| La ppm | 210 | 220 | 180 | 230 | 265 |
| Ce ppm | 720 | 690 | 1250 | – | 1500 |
| Nd ppm | 260 | 270 | 110 | – | 245 |
| Sm ppm | 40 | 40 | 40 | – | 61 |
| Eu ppm | 10 | 10 | 10 | – | 15 |
| Tb ppm | 10 | 10 | 10 | – | 9 |
| Yb ppm | 30 | 30 | 10 | 30 | 24 |
| Lu ppm | < 10 | < 10 | < 10 | < 10 | 4 |
| Hf ppm | 10 | 10 | – | – | 9 |
| Th ppm | 30 | 30 | 30 | – | 90 |

*Average of ICP, NAA and XRF analyses (not always all 3 techniques). It must be noted that large deviations around the "Ocean-averaged" manganese nodules values occur (e.g. McKelvey et al., 1979).

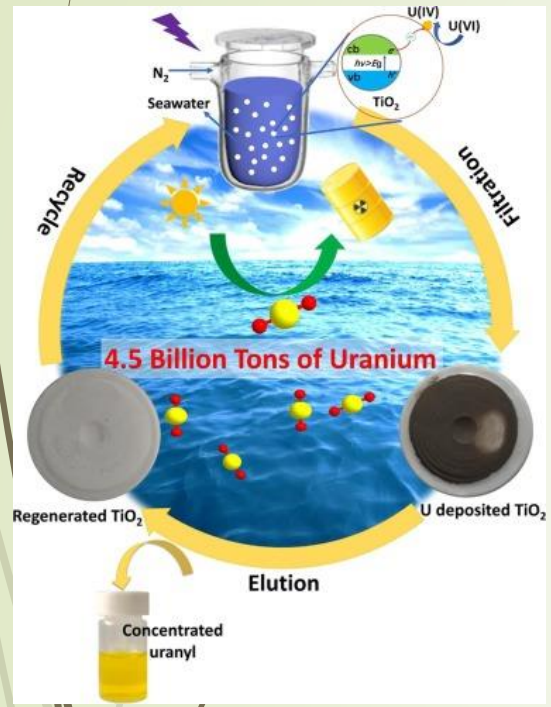
Black smokers

Basics of a hydrothermal vent - a Black Smoker



Uran z mořské vody

Strong complexation of glutaroimide-dioxime with U(VI) facilitates the recovery of uranium

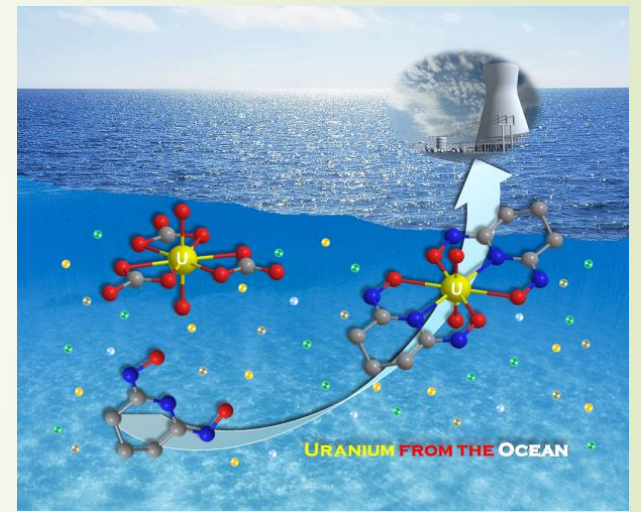


U(VI) extraction from seawater via photocatalysis can address the challenges for physicochemical adsorption and is a promising method for seawater uranium resource utilization.

To begin, extracting seawater uranium is harder than mining from land reserves as it involves a process called "adsorption," in which atoms, ions, or molecules adhere to a surface. Scientists have been designing different materials to serve as that surface that, when submerged in seawater, will "adsorb" uranium and hold it for extraction. Keeping these materials cost-efficient is important in relation to keeping the costs of seawater uranium low. Now, the DOE team has developed new adsorbents that brought the costs of seawater uranium extraction down by three to four times and in just five years.

The team created braids of polyethylene fibers that contain amidoxime, a chemical species that binds uranium. Tests show the new material has the ability to hold more than 6 grams of uranium per kilogram of adsorbent in 56 days of submersion in natural seawater.

Experts will convene at the University of Maryland-College Park for the International Conference on Seawater Uranium Recovery in July this year to further explore the potential of seawater uranium as a reliable energy source for the future. And while we may not have everything worked out just yet, things are looking bright.



0,003 ppm U in sea water
cca 3 mg/m3

Chemical Engineering
Journal Volume 365, 1 June
2019, Pages 231-241
Chemical Engineering
Journal
Photoconversion of U(VI) by
TiO2: An efficient strategy
for seawater uranium
extraction
PingLiaJingJing WangabYun
WangaJianJunLiangaBihong
HeaDuoqiangPanbQiaohuiF
anaXiangkeWangc

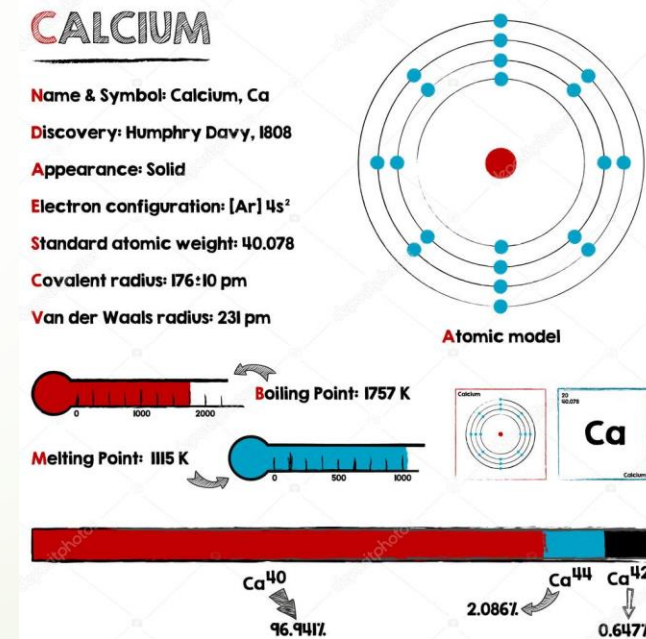
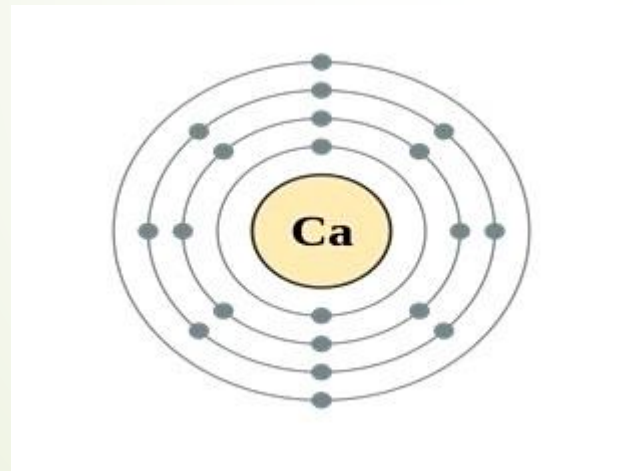
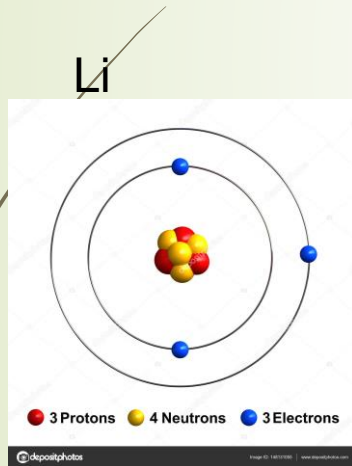
13,000 Years' Worth of Energy in the Oceans
We have 4.5 billion tons of uranium in seawater. Half of that amount is enough to power nuclear plants worldwide for 6,500 years. However, unfortunately, the costs of extracting uranium from seawater is three times the current cost of uranium mined from land. That said, researchers believe this source may one day be critical to sustaining our energy needs, and to that end, efforts to extract uranium from the seas began in the 1960's. And our efforts have continued from there.

"For nuclear power to remain a sustainable energy source, an economically viable and secure source of nuclear fuel must be available," said Phillip Britt, technical and outreach leader of the team started by the U.S. Department of Energy (DOE) in 2011. And now, it seems that we have a much cheaper way of obtaining this material.

<https://futurism.com/uranium-seawater-keep-lights-13000-years/>

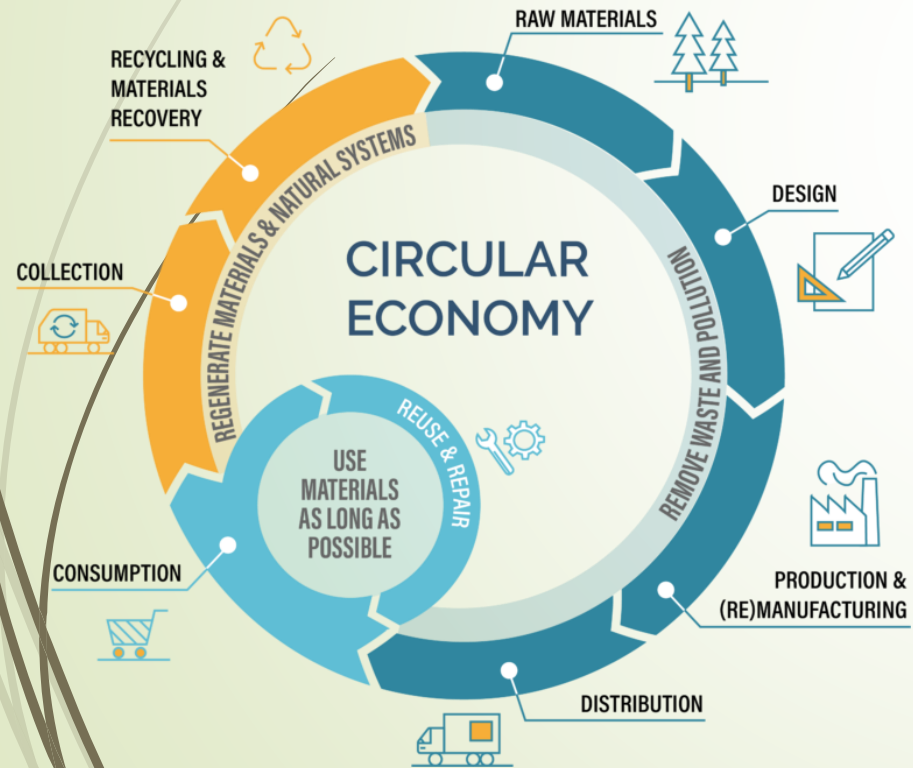
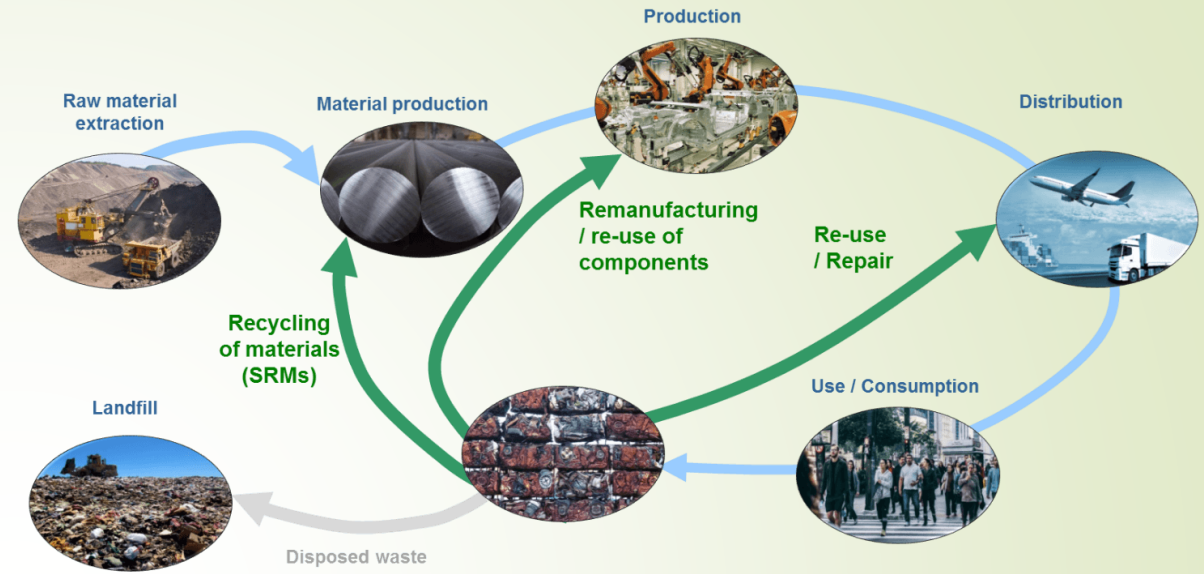
Search for substitutes

- replacement of traditional raw materials with new ones
- using the properties of more available materials:
replacement of Li in batteries with calcium - the future?



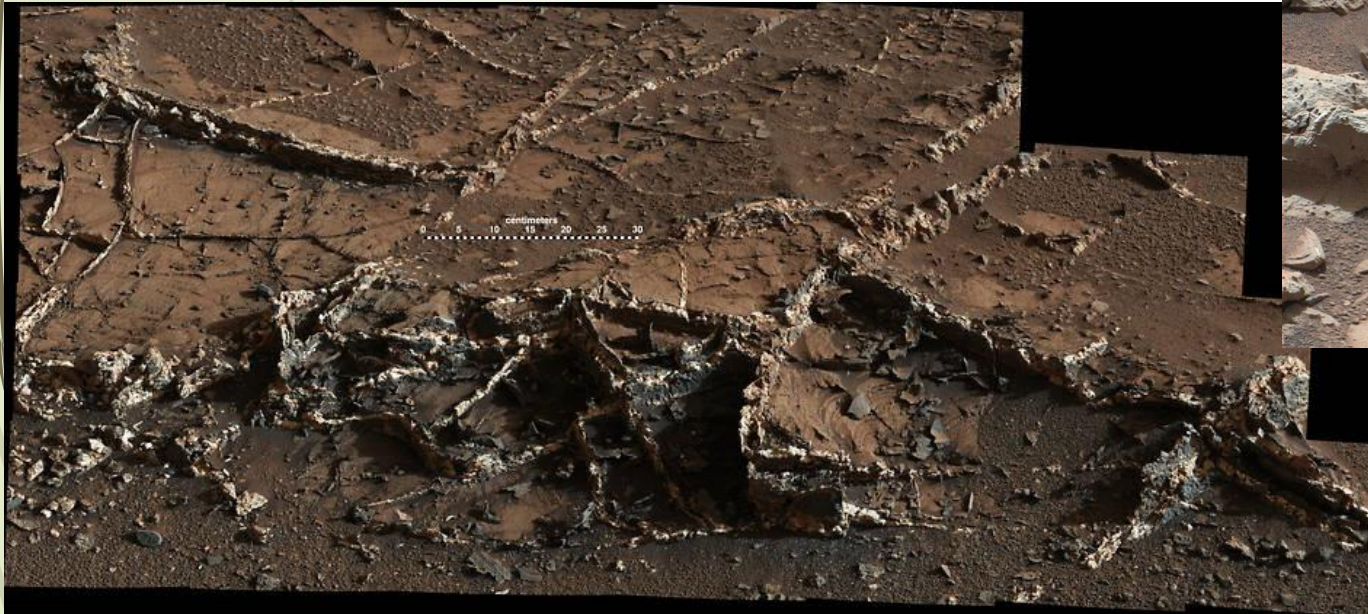
https://www.euro.cz/byznys/jak-nahradit-drahe-lithium-v-nemecku-zkousi-baterie-s-vapnikem-1470590#utm_medium=selfpromo&utm_source=euro&utm_campaign=copylink

Recyklace



Veins on Mars

indikace hydrotermálních procesů



This view from the Mast Camera (Mastcam) on NASA's Curiosity Mars rover shows a network of two-tone mineral veins at an area called "Garden City" on lower Mount Sharp. The veins combine light and dark material. The veins at this site jut to heights of up to about 2.5 inches (6 centimeters) above the surrounding rock, and their widths range up to about 1.5 inches (4 centimeters). Figure 1 includes a 30-centimeter scale bar (about 12 inches).

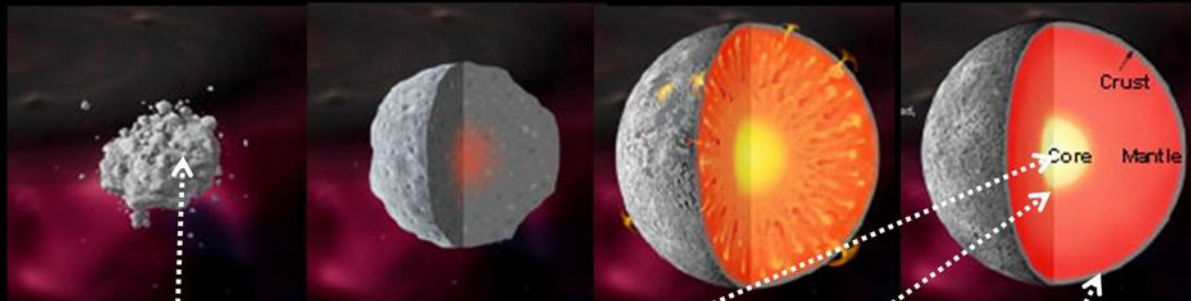


This image of an outcrop at the "Sheepbed" locality, taken by NASA's Curiosity Mars rover with its right Mast Camera (Mastcam), shows well-defined veins filled with whitish minerals, interpreted as **calcium sulfate**. Mastcam obtained these images the 126th Martian day, or sol, of Curiosity's mission on Mars (December 13, 2012). The view covers an area about 16 inches (40 centimeters) across. A superimposed scale bar is 8 centimeters (3.15 inch) long.

Asteroidy – zdroj?

Different Asteroid & Meteorite Types

Source: Smithsonian Museum of Natural History http://www.mnh.si.edu/earth/text/5_1_4_0.html



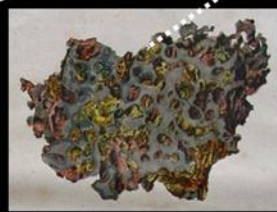
Chondritic Stony Meteorite

Asteroid Type C



Iron Meteorite

Asteroid Type M



Pallasite Meteorite

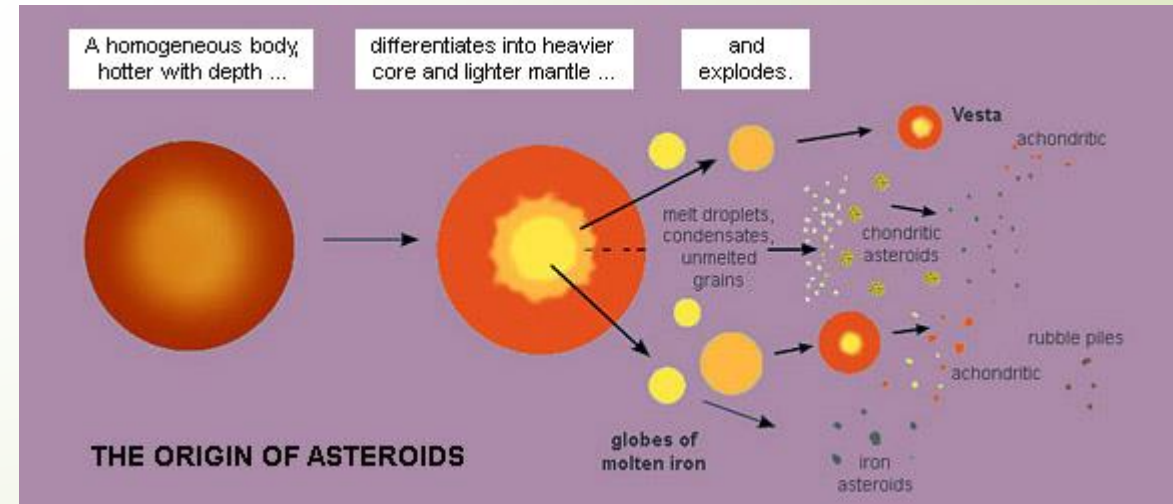
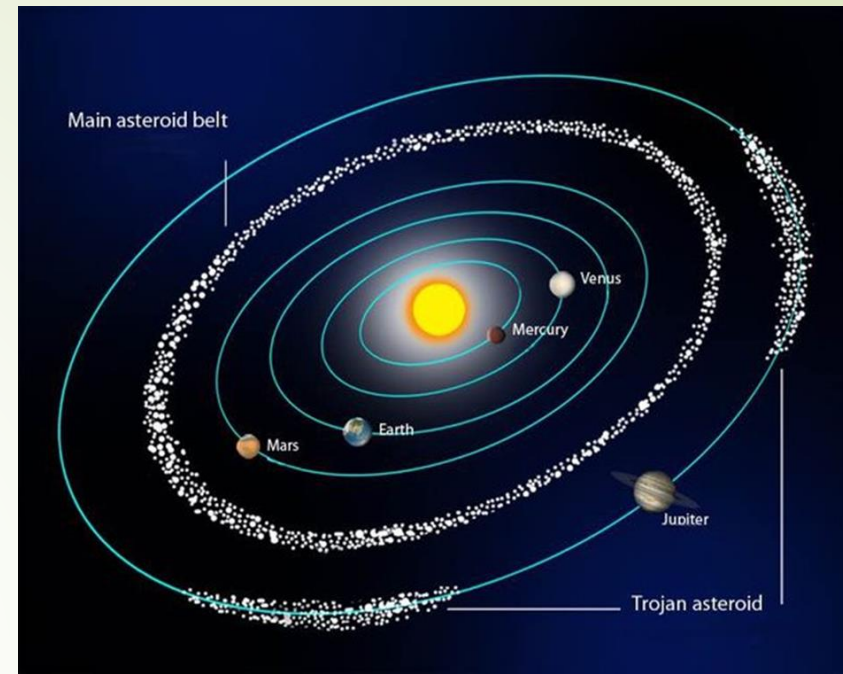
pallasite: kov Fe-Ni + hornina a minerály



Achondritic Stony Meteorite

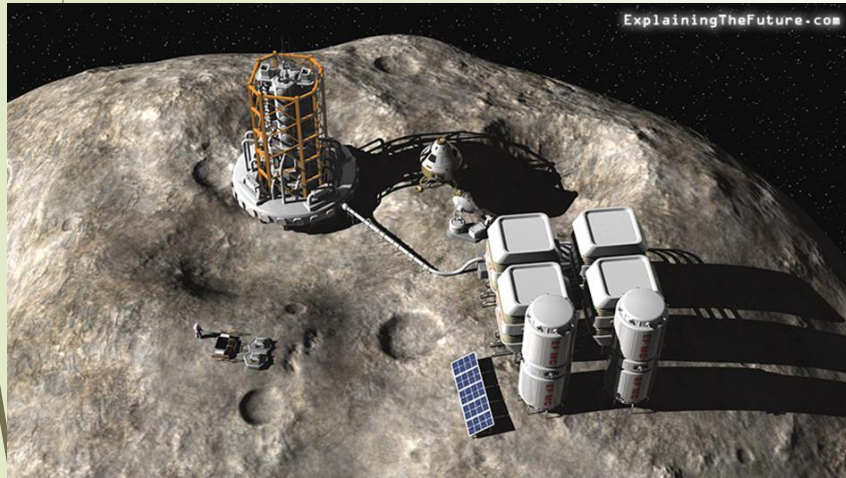
Asteroid Type S

License: Wikimedia Creative Commons



<https://www.earthhistory.org.uk/the-old-world-destroyed/piecing-asteroids-back-together>

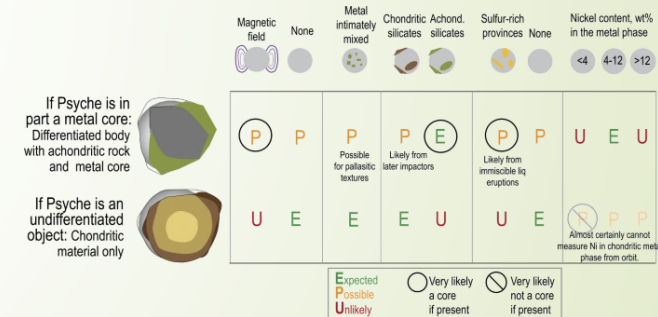
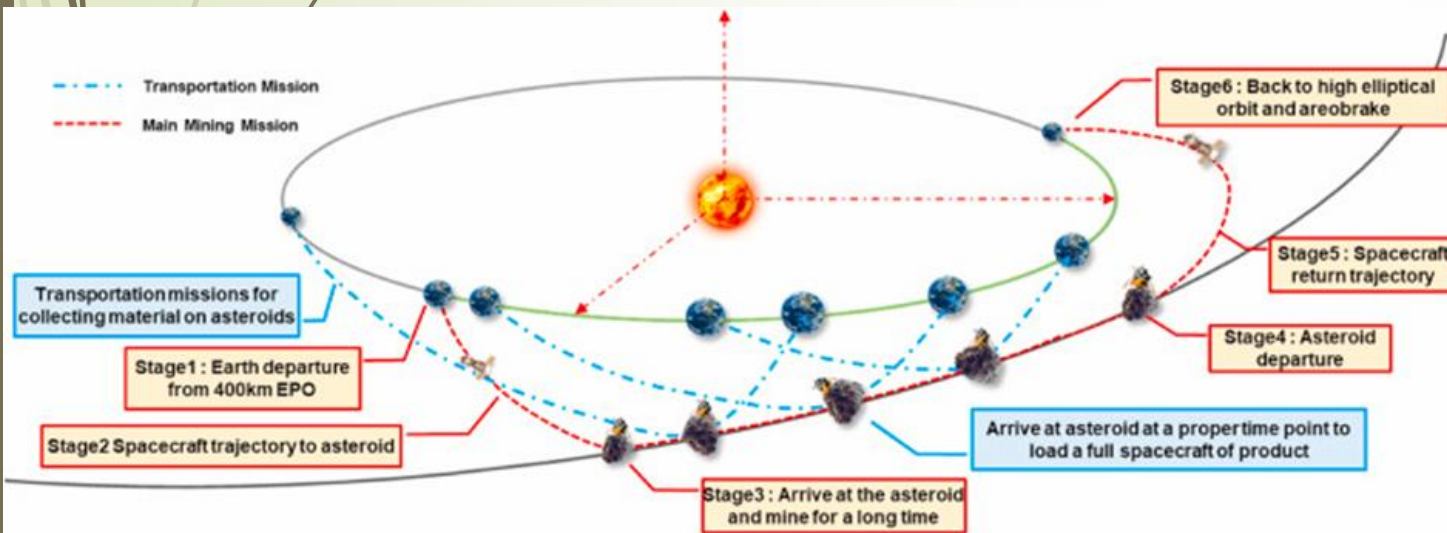
„Vytěžení“ asteroidů



A mission to investigate the **metal-rich asteroid Psyche**, which might be the exposed core of a long-dead planet, has been given the go-ahead by NASA. The mission's fate had previously been in doubt after technical difficulties made it miss its 2022 launch window. According to Forbes, 16 Psyche, a 140-mile-wide/226-kilometer-wide asteroid could contain a **core of iron, nickel and gold** worth \$10,000 quadrillion (10¹⁵).



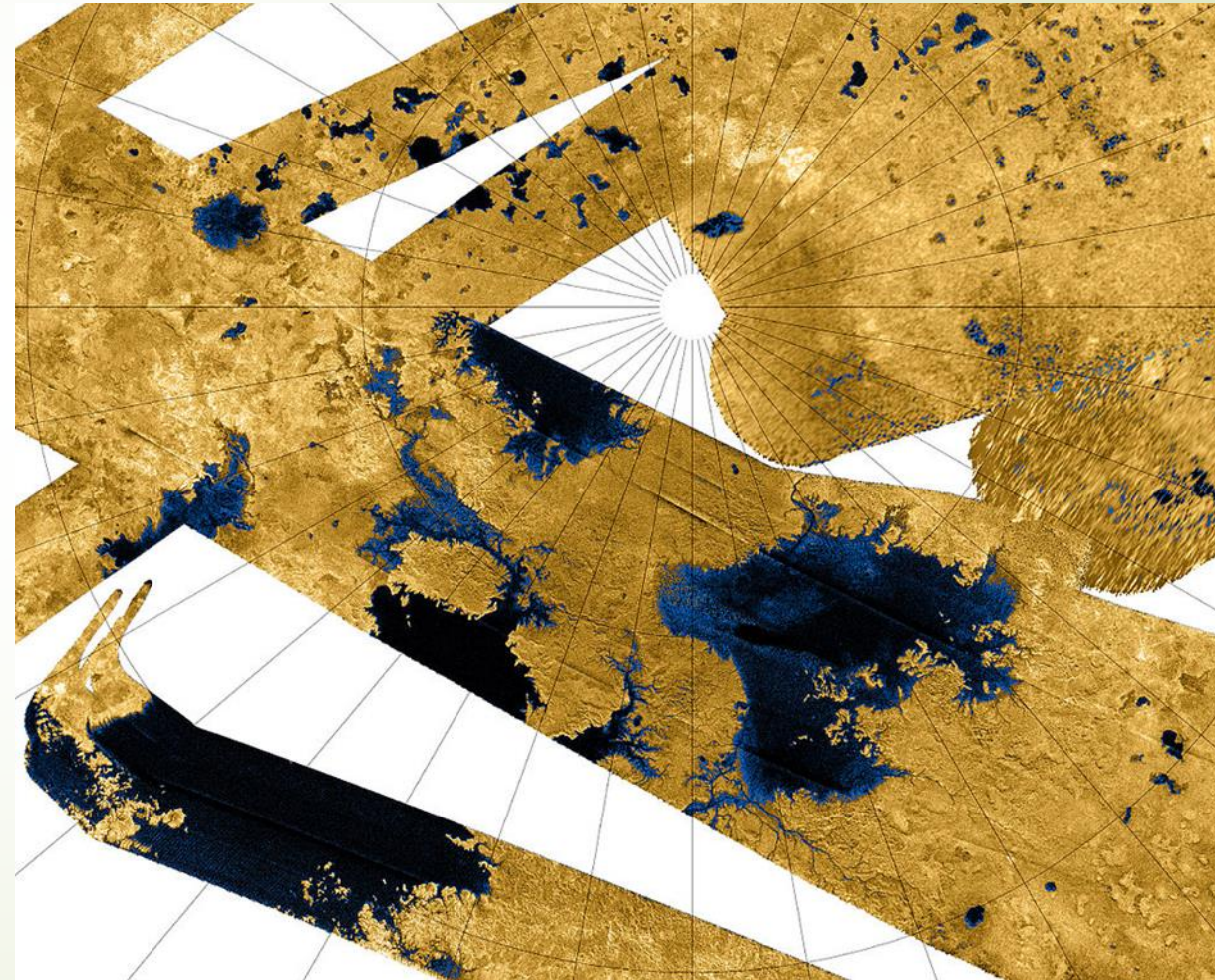
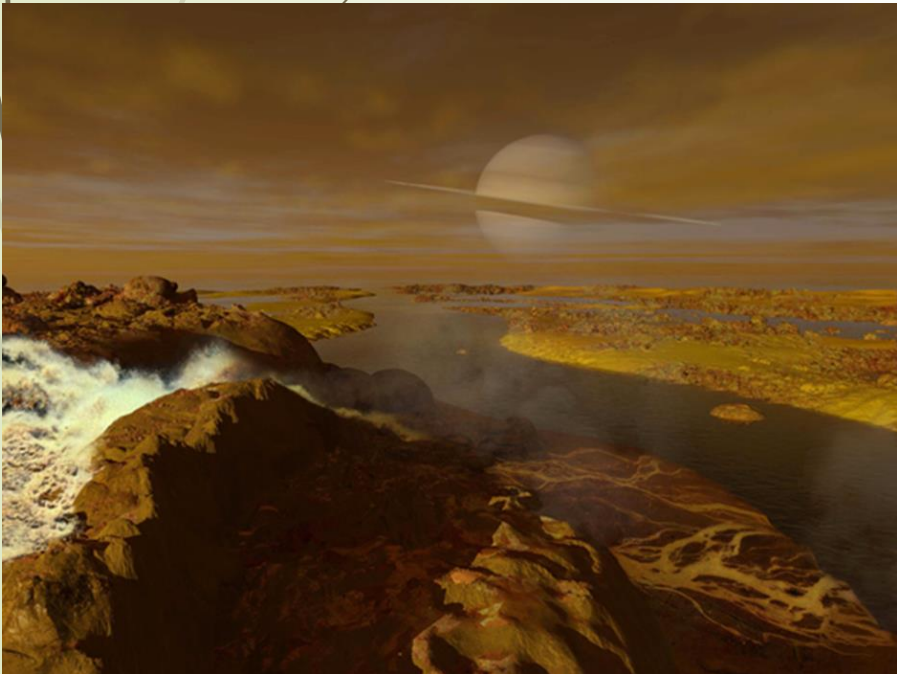
16 Psyche, the large metallic asteroid ideal for space mining. The theory goes that something smashed into 16 Psyche a few billion years ago, creating a massive crater about four miles deep and 33 miles wide.



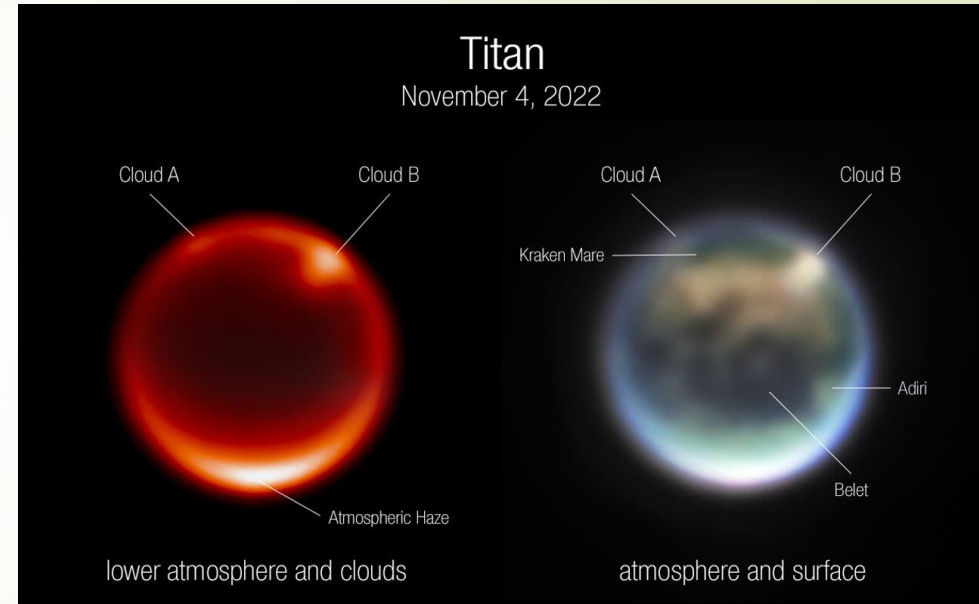
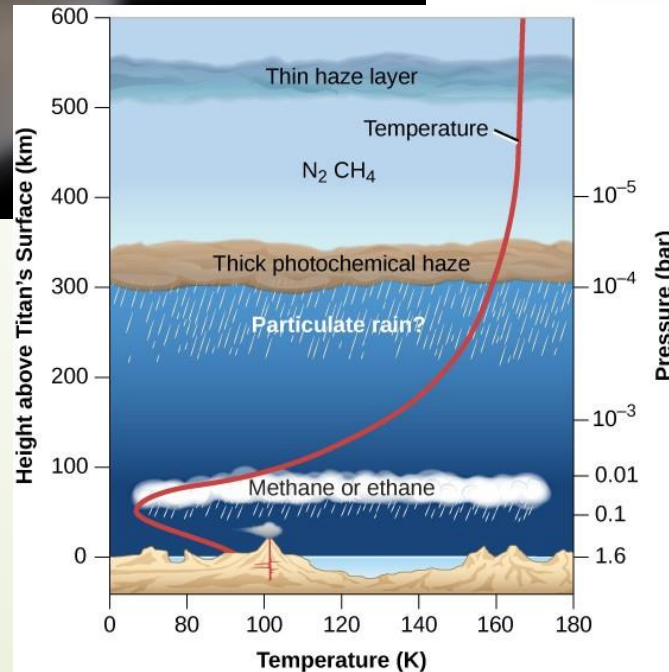
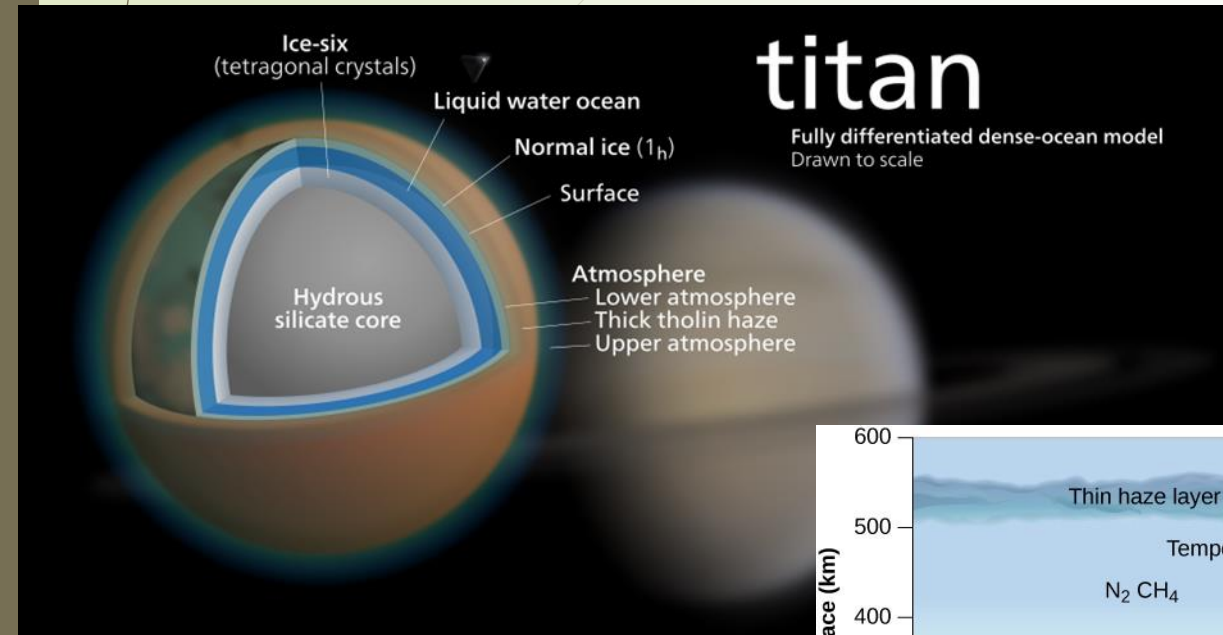
This matrix of instrument measurement interpretations along the top shows the requirement for multiple measurements to support either of the origin hypotheses at left. Only a few measurements are probably definitive on their own (strong magnetic field, achondritic silicate provinces, and sulfur-rich volcanism each likely indicate Psyche is a core). Expected = Likeliest outcome according to current models; Possible = Outcome predicted in some scenarios; Unlikely = Not predicted in current models. See text for detailed explanation, and for further explanation of how the instruments can discriminate between achondritic and chondritic silicates, see Elkins-Tanton et al. (2020)

Titan's methane

False-color Cassini radar mosaic of Titan's north polar region. Blue coloring indicates low radar reflectivity, caused by hydrocarbon seas, lakes and tributary networks filled with liquid ethane, methane and dissolved N_2 . About half of the large body at lower left, Kraken Mare, is shown. Ligeia Mare is at lower right.



Titan – vrstvy, atmosféra

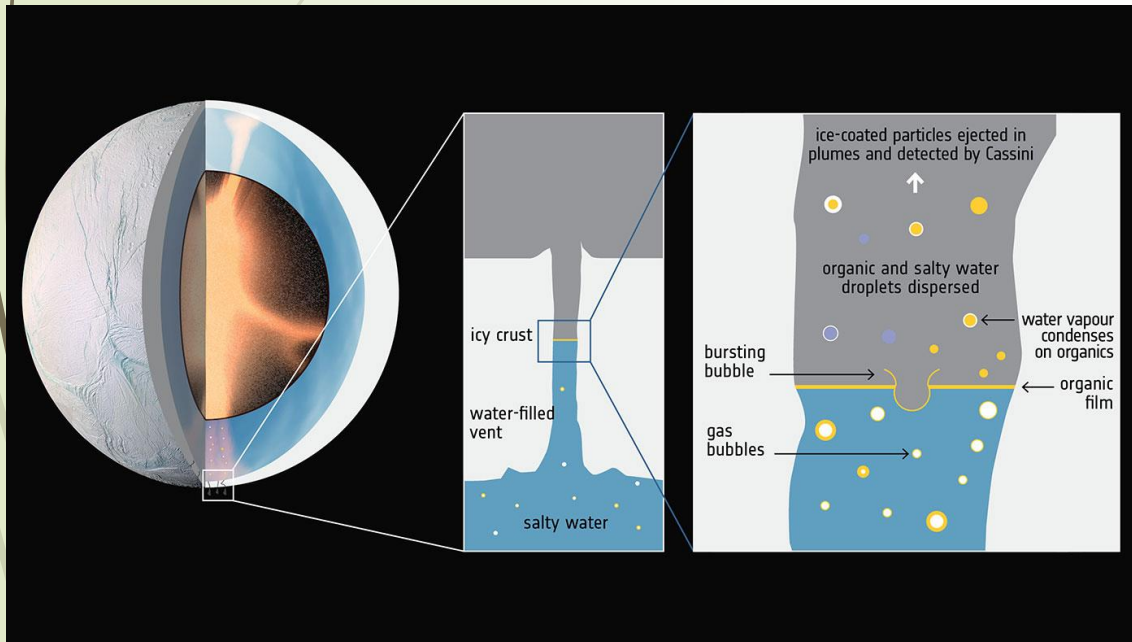


These are images of Saturn's moon Titan, captured by the NASA/ESA/CSA James Webb Space Telescope's NIRCcam instrument on 4 November 2022. The image on the left uses a filter sensitive to Titan's lower atmosphere. The bright spots are prominent clouds in the northern hemisphere. The image on the right is a color composite image. Several prominent surface features are labeled: Kraken Mare is thought to be a methane sea; Belet is composed of dark-colored sand dunes; Adiri is a bright albedo feature.

<https://esaweb.org/images/titan1/>

Voda (led) a hydráty plynů(?) v blízkém vesmíru

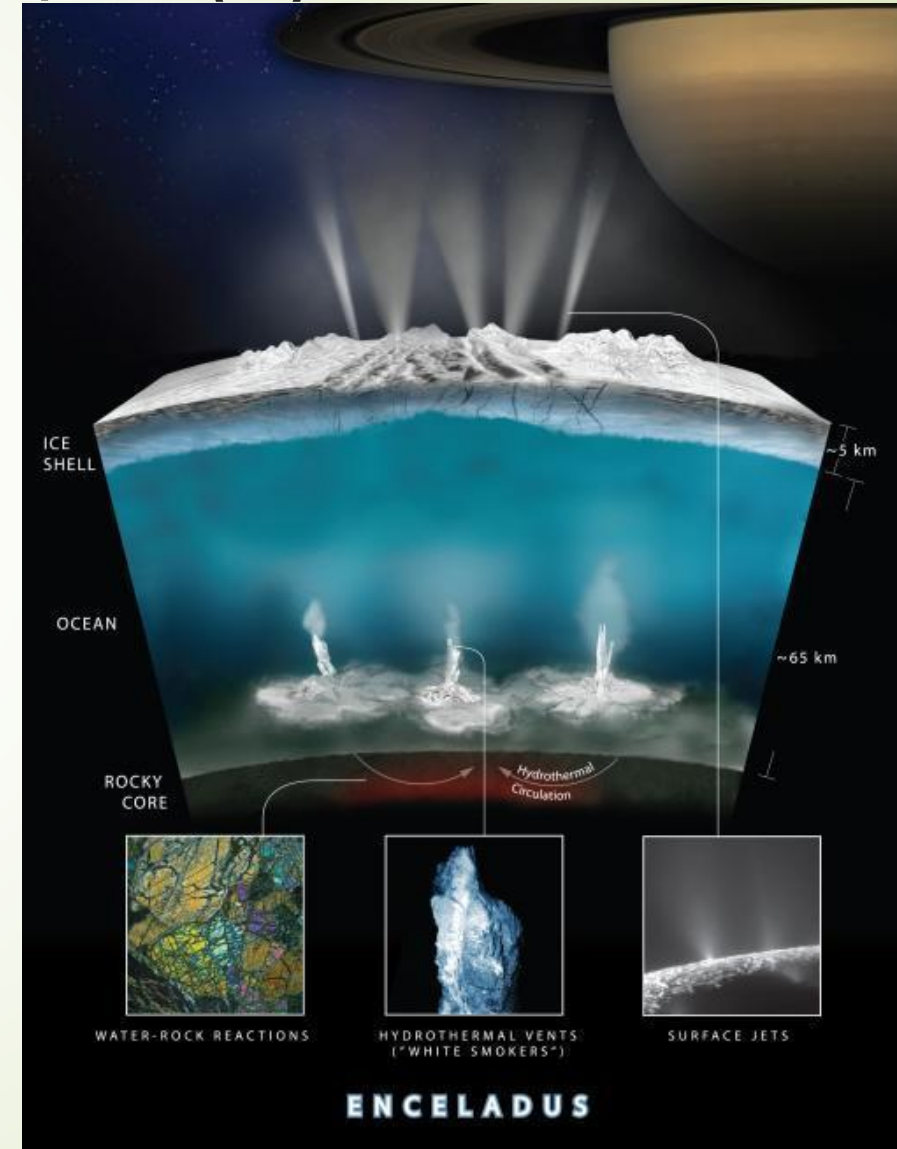
Hydrothermal activity in Enceladus' core and the rise of organic-rich bubbles.
Image Credit: ESA; F. Postberg et al (2018)



the ingredients of amino acids — were detected by NASA's Cassini spacecraft in the ice grains emitted from Saturn's moon Enceladus. Powerful hydrothermal vents eject material from Enceladus' core into the moon's massive subsurface ocean. After mixing with the water, the material is released into space as water vapor and ice grains. Condensed onto the ice grains are nitrogen- and oxygen-bearing organic compounds.

<https://ras.ac.uk/news-and-press/research-highlights/new-organic-compounds-found-enceladus-ice-grains>

De Toffoli, B., Pozzobon, R., Massironi, M. et al. Surface Expressions of Subsurface Sediment Mobilization Rooted into a Gas Hydrate-Rich Cryosphere on Mars. *Sci Rep* 9, 8603 (2019). <https://doi.org/10.1038/s41598-019-45057-7>



<https://www.spaceflightinsider.com/missions/solar-system/saturns-moon-enceladus-has-conditions-that-could-support-microbial-life/>

Mars – hydráty jako zdroj pro osídlení