

Question: what is worth teaching to everyone from Soil Mechanics?
(civil engineering subject)

Answer:

What happens when soil compresses¹

Part 2

¹ **compress:** to press or squeeze together, to undergo compression (Webster)

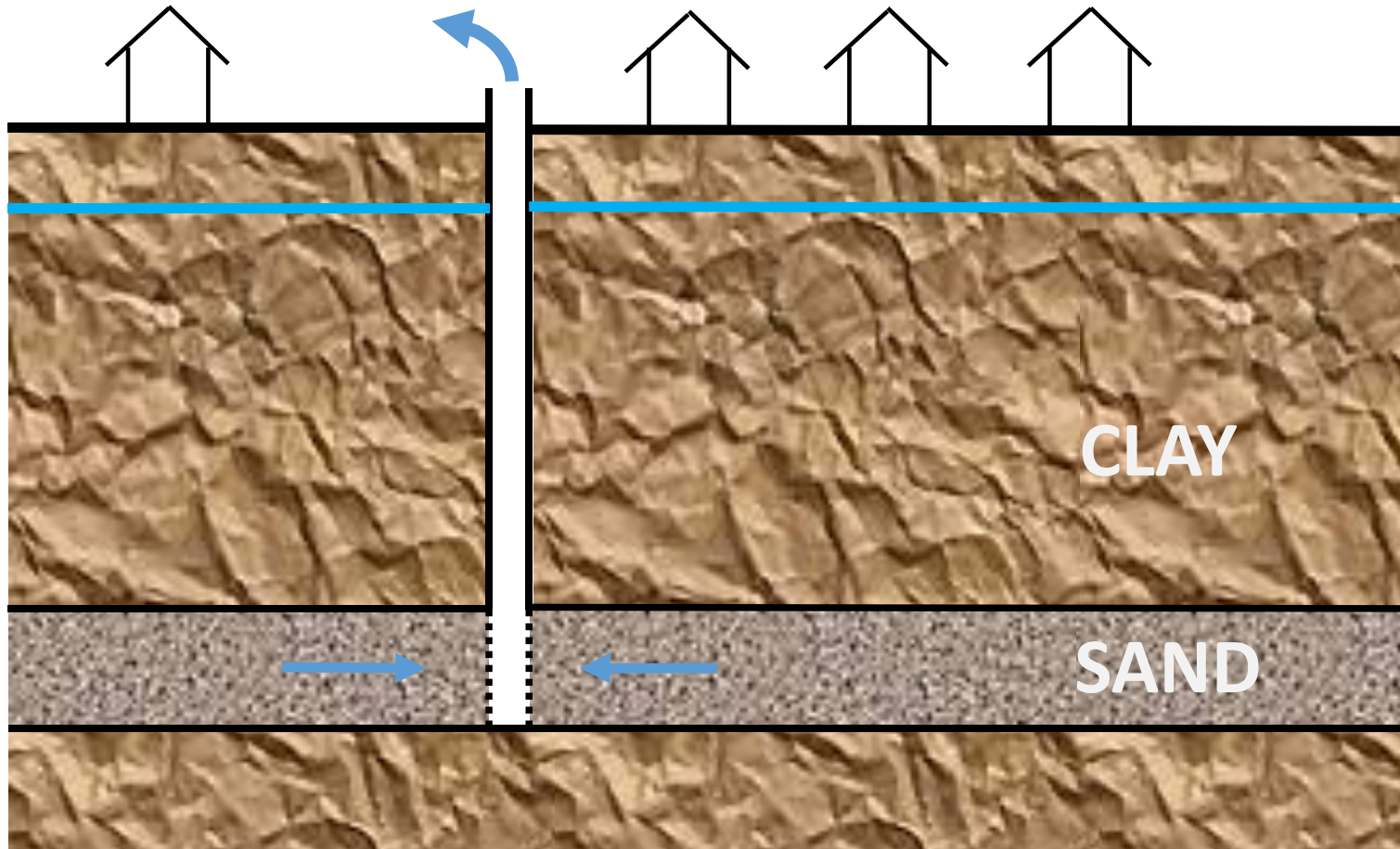
Goals of lesson in 3 parts + summary

- describe what happens when soil compresses
- link the description of soil settlement to the quantitative prediction of settlement (this is what civil engineers need to know)

Part 2

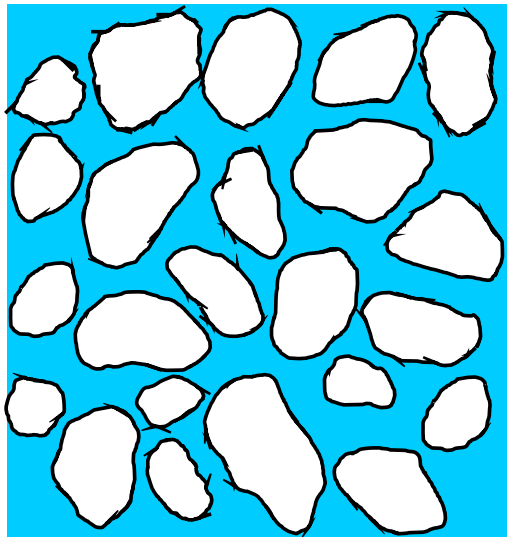
- SOIL SETTLEMENT DUE TO PUMPING WATER
- SETTLEMENT IN VENICE (several centimeters) – SETTLEMENT IN MEXICO CITY (several meters)

Changing the problem: we pump water

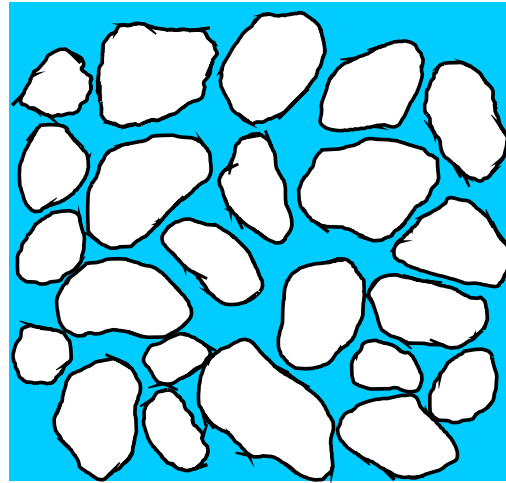


Pumping → water escapes → soil compresses*

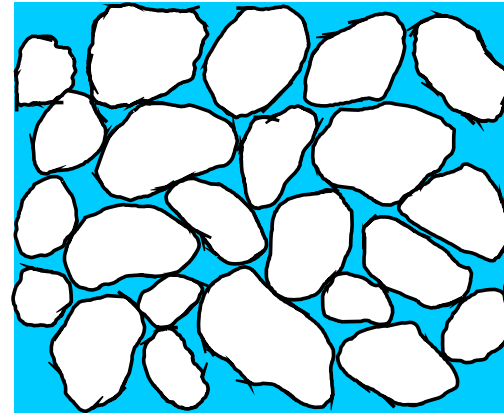
* Without air entering in the soil pores



← A →



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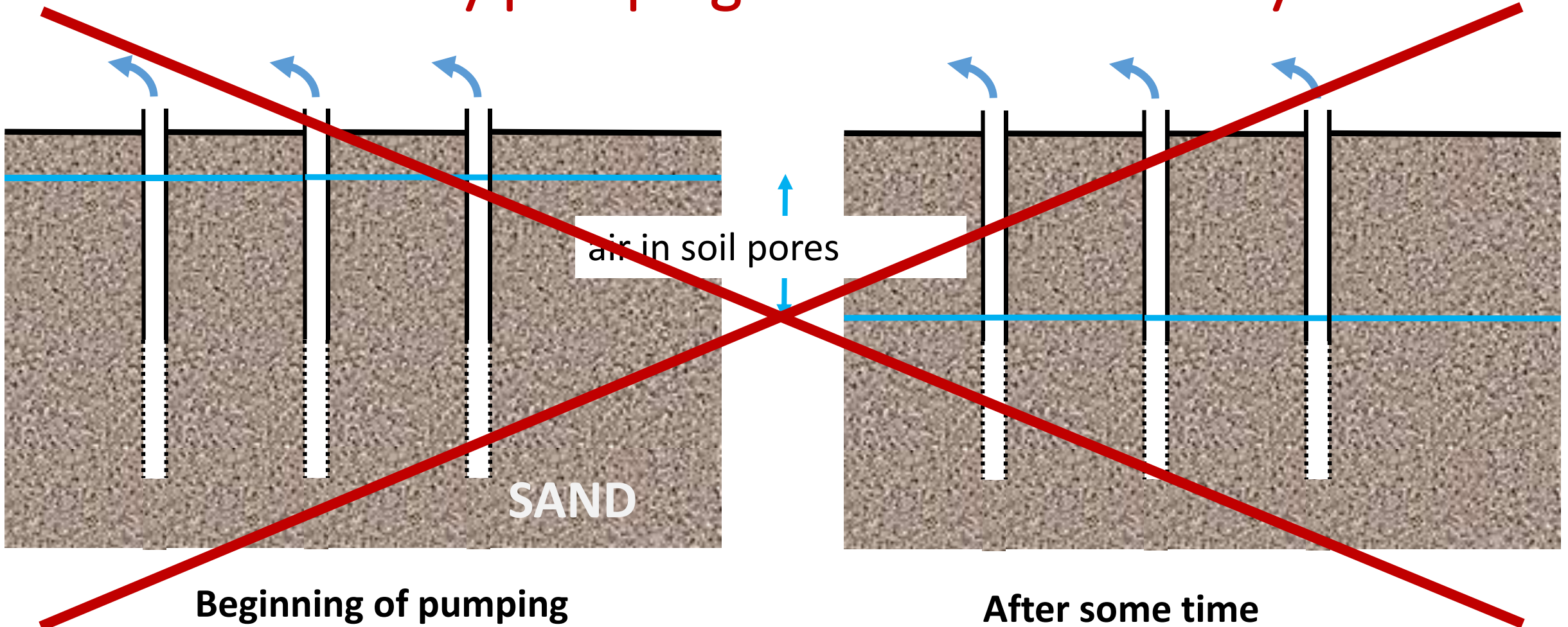


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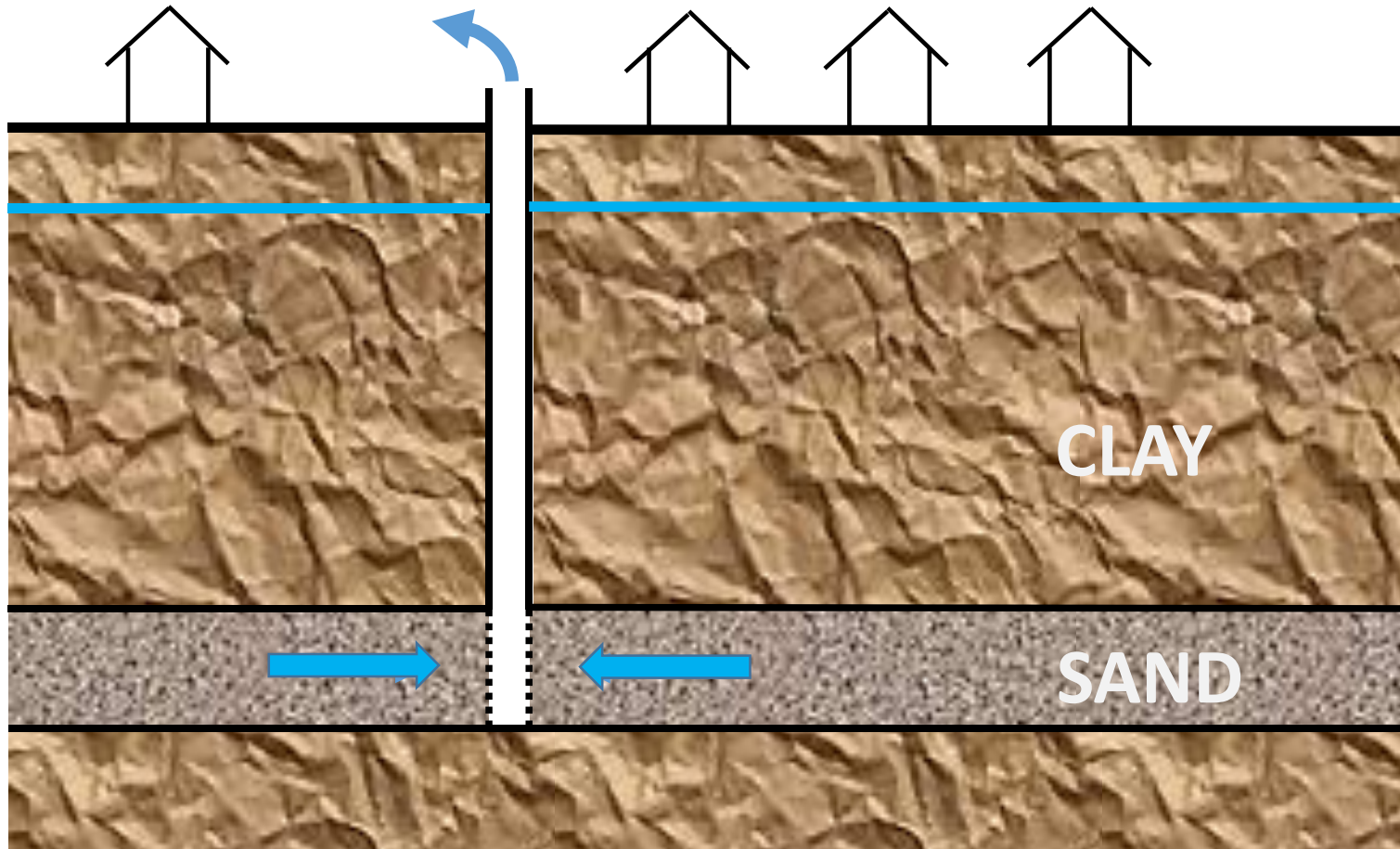
⇒ water
pumping

CAUTION! soil remains saturated:

we don't study pumping from surface soil layer



The case of water pumping under study



Clay on top of sand remains saturated (=pores filled with water)

We pump from a sand layer at a significant depth

Venice: flat islands in lagoon



Venice: broader area

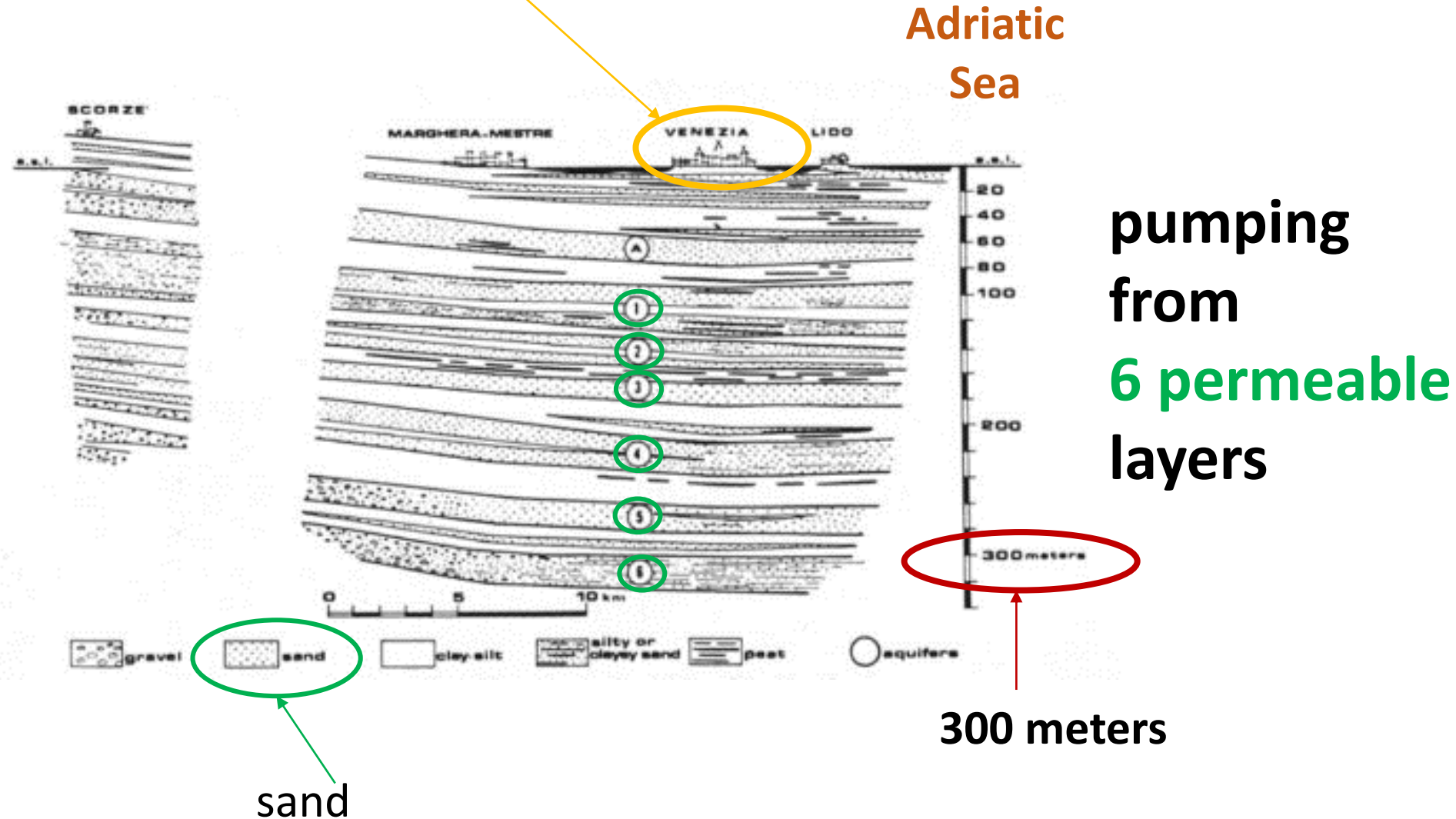


Marghera (industrial area): water pumping

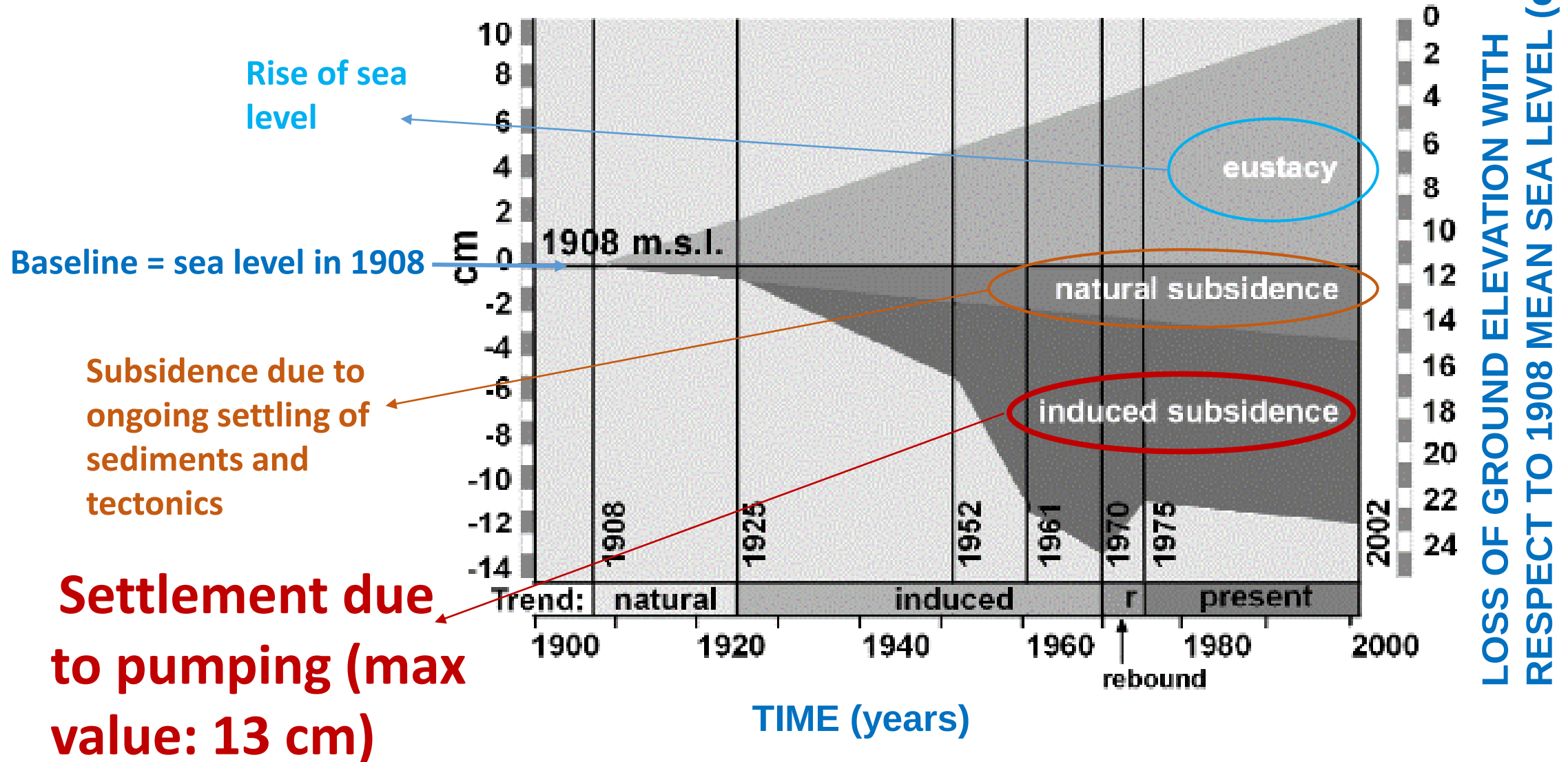


Cross section on next slide

Venice area, soil profile: alternating layers of sand and silt



Venice: results of pumping (1925-1975)



Mexico City (population: 21 million)



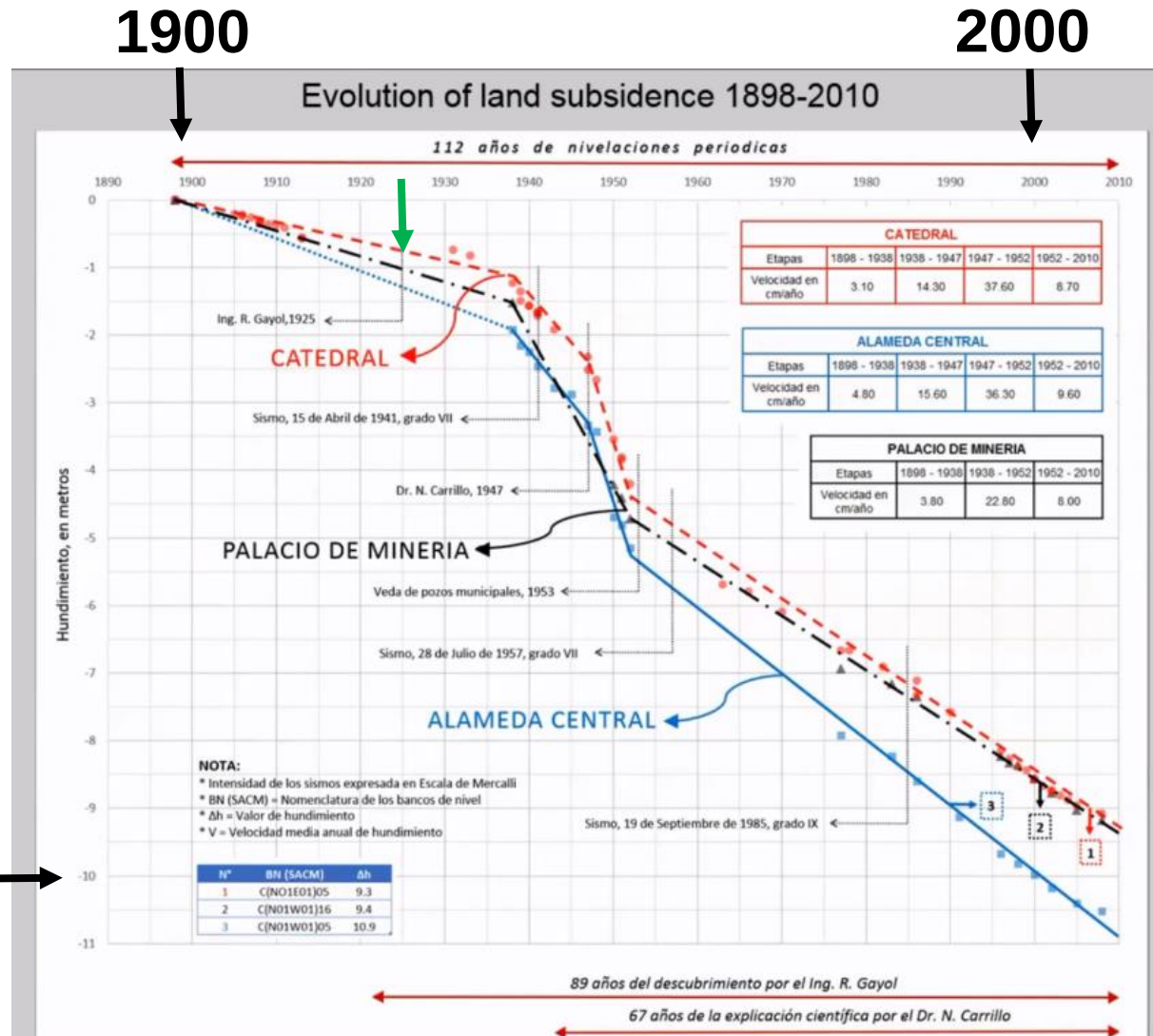
Settlement in Mexico City

Pumping begins late 19th century and continues today

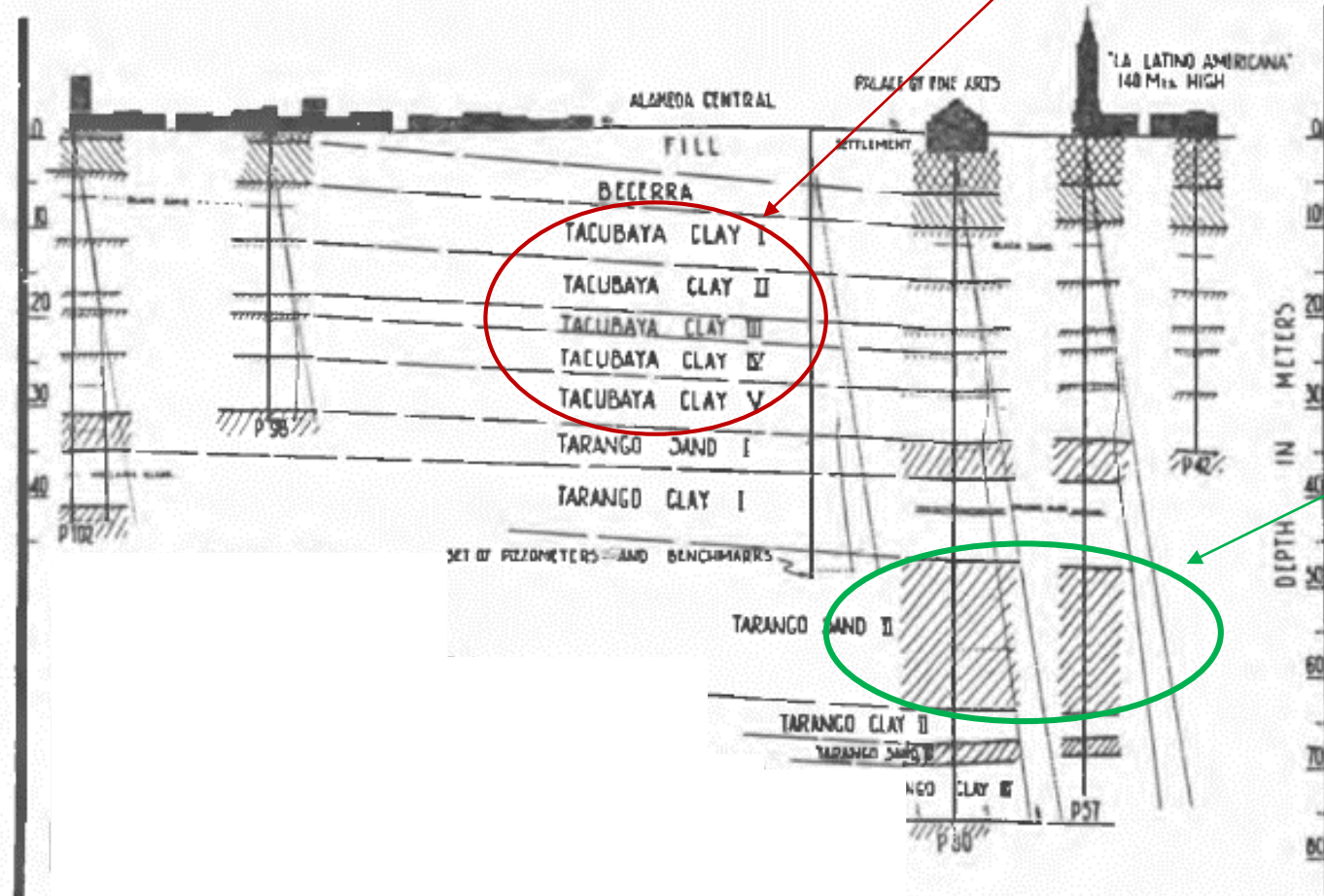
First reports of problems with land subsidence: **1925**

Pumping depth: 50 – 500 m

10 meters →

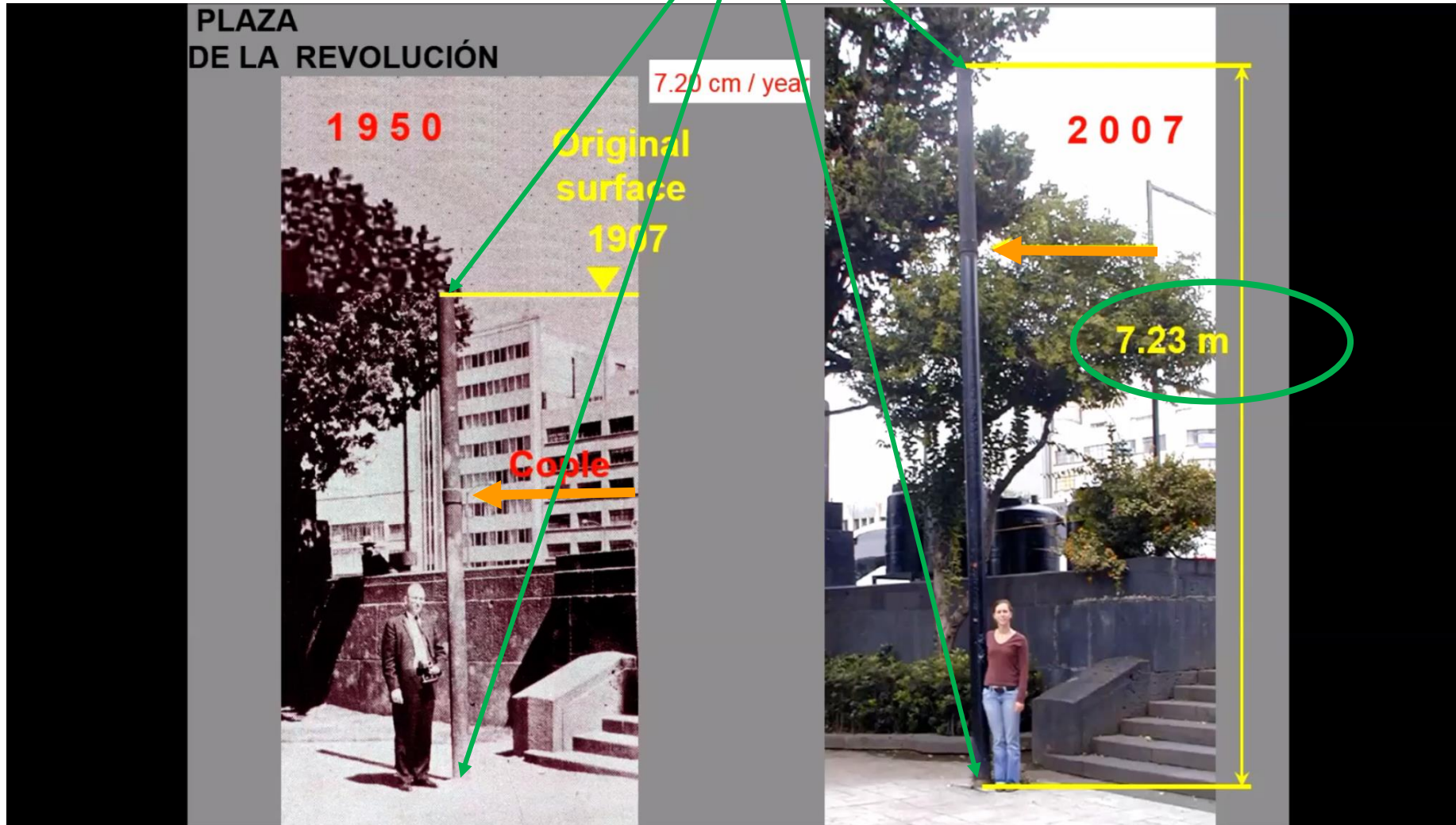


Mexico City, soil profile: **mainly clay** with layers of sand in between



**Pumping from
sand layer
closest to land
surface**

Settlement evidence: borehole casing sticks out more and more while soil subsides



Venice – Mexico City

- Pumping over decades causes subsidence of land surface
 - 13 centimeters in Venice, 7-10 meters in Mexico City
- Why so big a difference in the two cities?
 - Because clay in the subsurface of Mexico City is very soft: the volume of soil pores is 5 – 10 larger than the volume of soil grains
- Caution! This sizeable settlement is not due to the sandy layers from which we pump water – it is due to the neighboring layers
 - In the next part we will see how pumping from the sand layers affects the neighboring fine-grained layers

Pumping = soil compression: main ideas

- If we pump water in built environments, we learned to expect problems because soil settles and land subsides
- Famous cases of settlement due to pumping
 - Venice: relatively small, but problematic settlement because the land surface is very close to sea level
 - Mexico City: unusually large settlement because the city is built on deep layers of clay with very large volume of soil pores

Attribution of sources

- Slides 7, 8, 11: pictures from Creative Commons: <https://www.flickr.com/creativecommons/>
- Slides 8, 9: Gambolati, G., P. Gatto and R.A. Freeze, 1974, Mathematical formulation of the subsidence of Venice 2. Results, Water Resources Research, 10(3):563-577.
- Slide 10: Carbognin, L., P. Teatini and L. Tosi, 2005, Land Subsidence in the Venetian area: known and recent aspects, Giornale di Geologia Applicata, doi:10.1474/GGA.2005-01.0-01.0001
- Slides 12, 14: Auvinet, G., 2016, Geotechnical challenges in Mexico City clay, ISSMGE [Webinar](#)
- Slide 13: Zeevaert, L., 1953, Pore pressure measurements to investigate the main source of subsurface subsidence in Mexico City, Proceedings of the III International Conference on Soil Mechanics, Zurich.