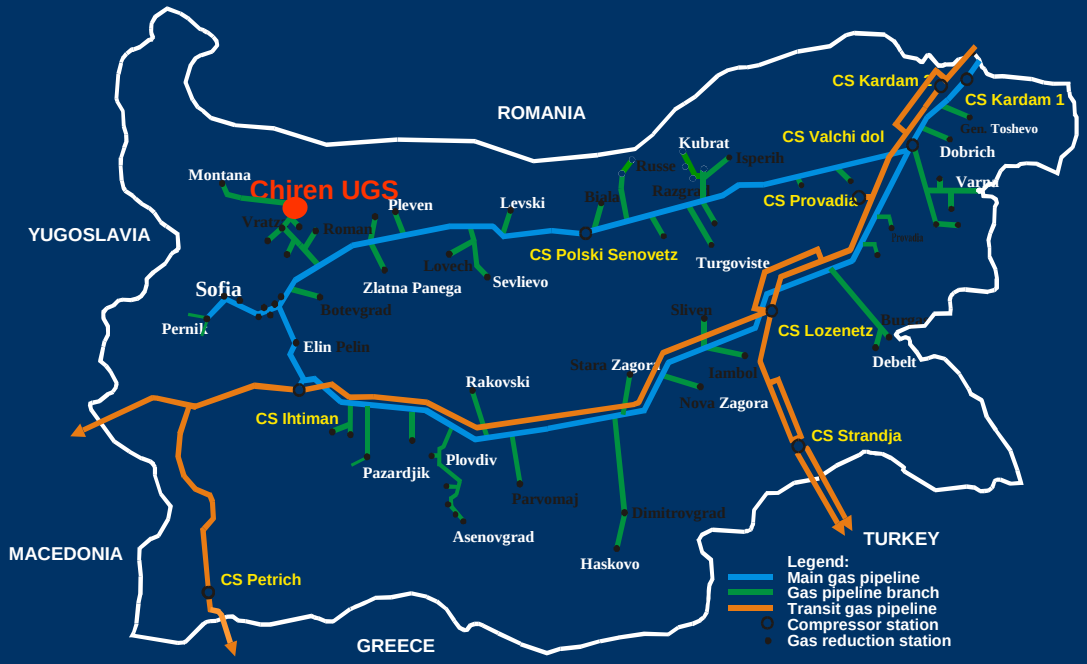
Estimation of maximum permissible depressions of operational wells for the effective exploitation of Chiren UGS / Bulgartransgaz EAD

Authors:

Dimitar Shterev, M.Sc. - Head of Gas Storage dept.,
Roumen Ognianov, Ph.D. - Consultant of Gas Storage dept.,
Mladen Yordanov, M.Sc. - Head of Chiren UGS
Ivaylo Pandurski, M.Sc. – Deputy Head of Chiren UGS



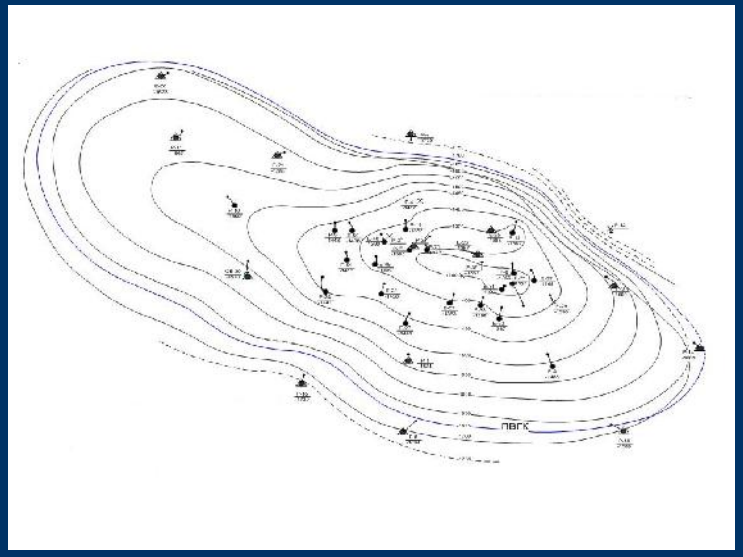
BULGARTRANSGAZ

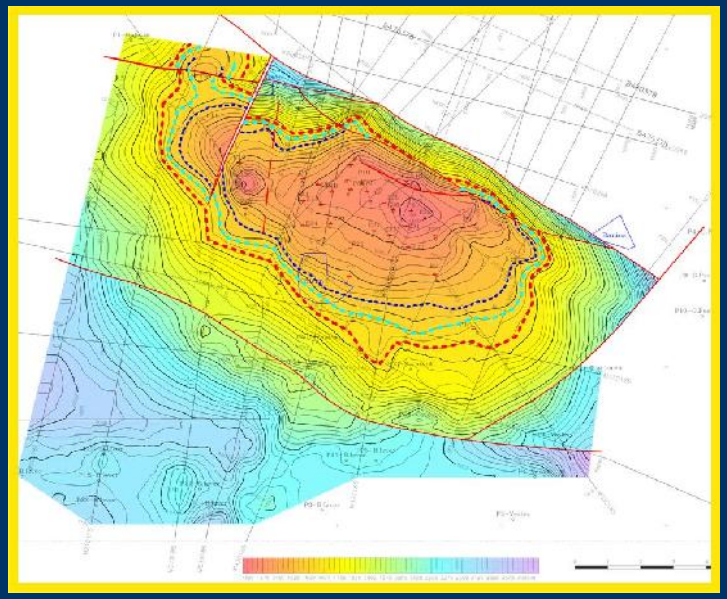
Chiren UGS surface facilities

BULGARTRANSGAZ

Structural map on the top of the gas storage reservoir

/Lower Jurassic limestones and sandstones/





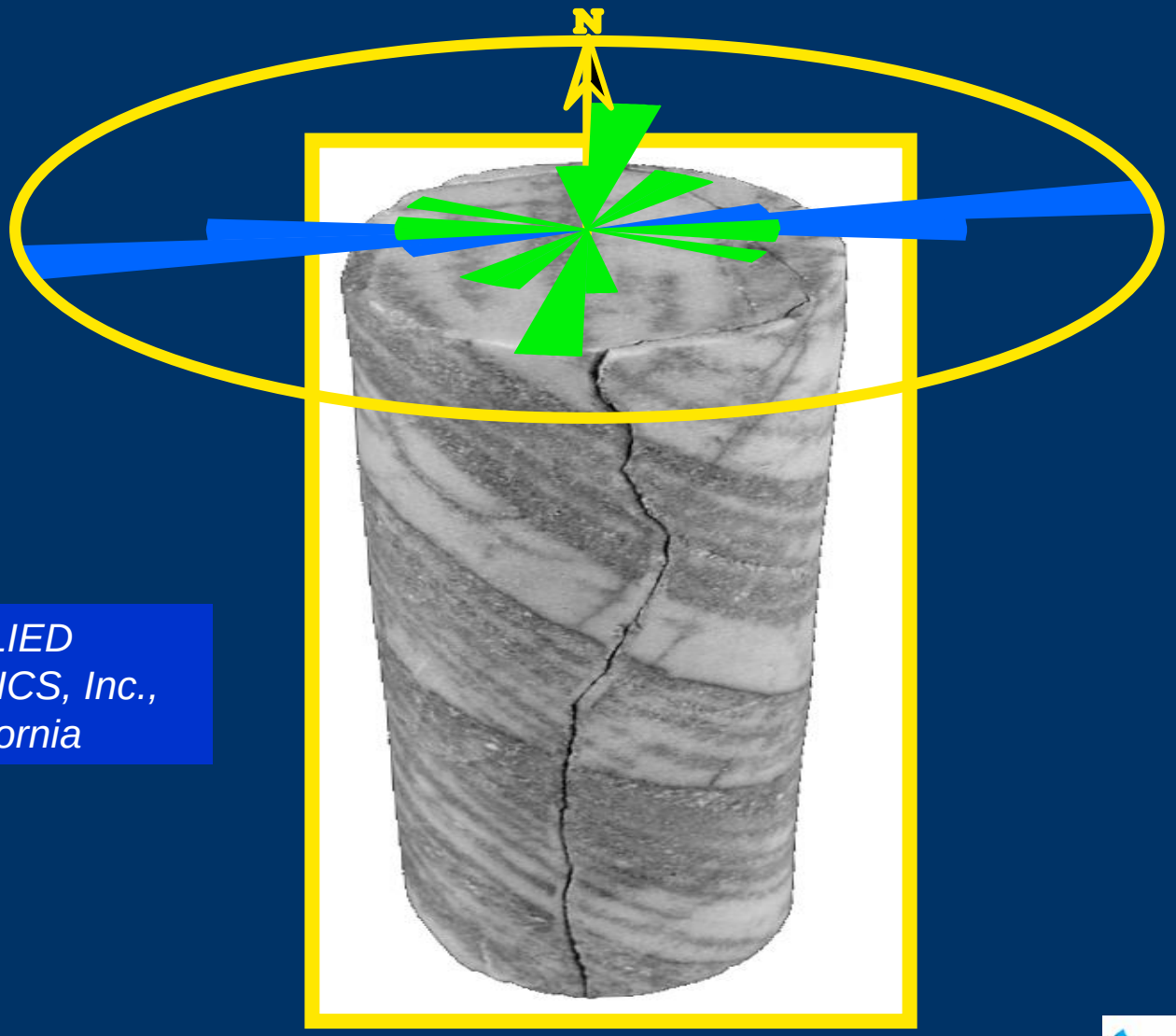
Initial Water Gas Contact:
- 1675 m

Water-Gas Contact in fractures:
- 1650 m

Water-Gas Contact in matrix:
- 1575 m

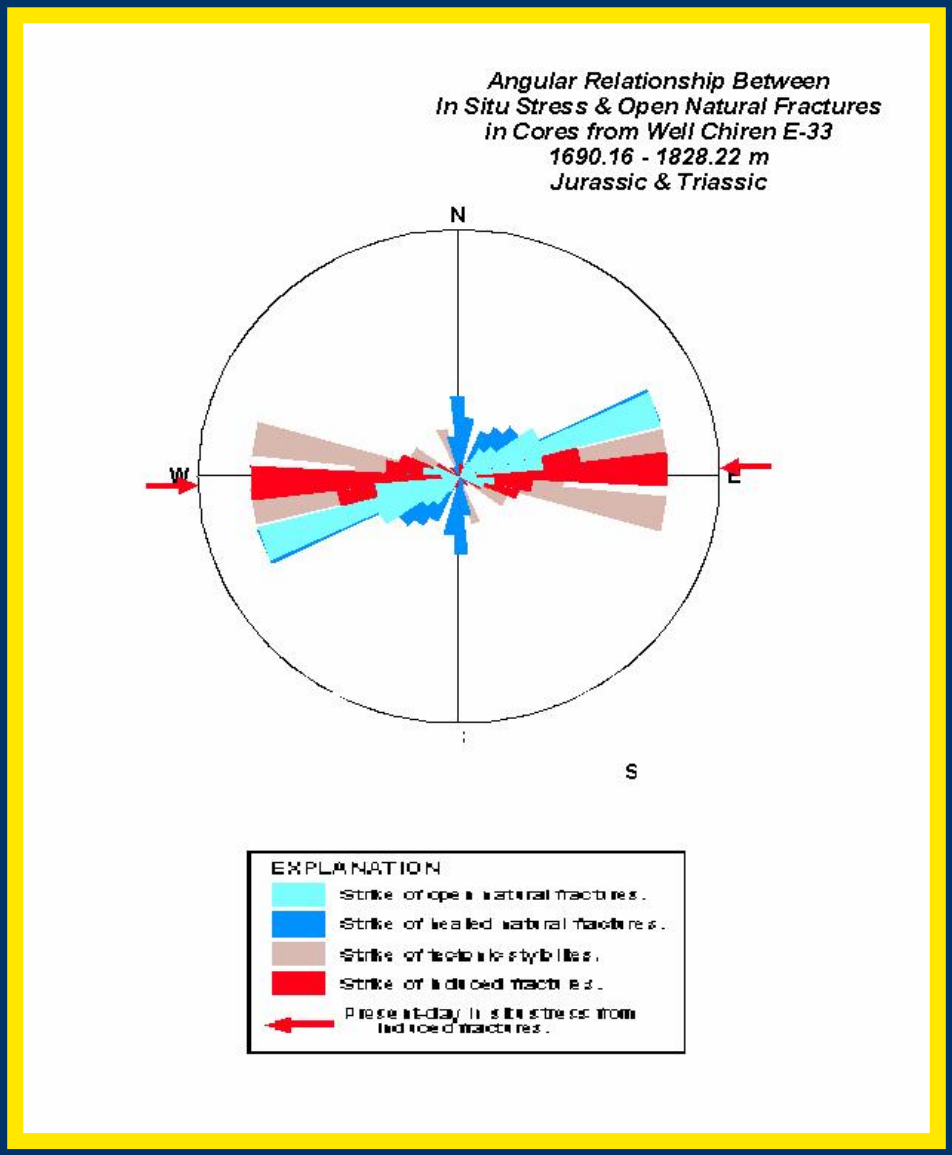
BULGARTRANSGAZ

Evaluation of fractures' directions from paleomagnetically oriented core



1999, from APPLIED PALEOMAGNETICS, Inc., Santa Cruz, California

BULGARTRANSGAZ



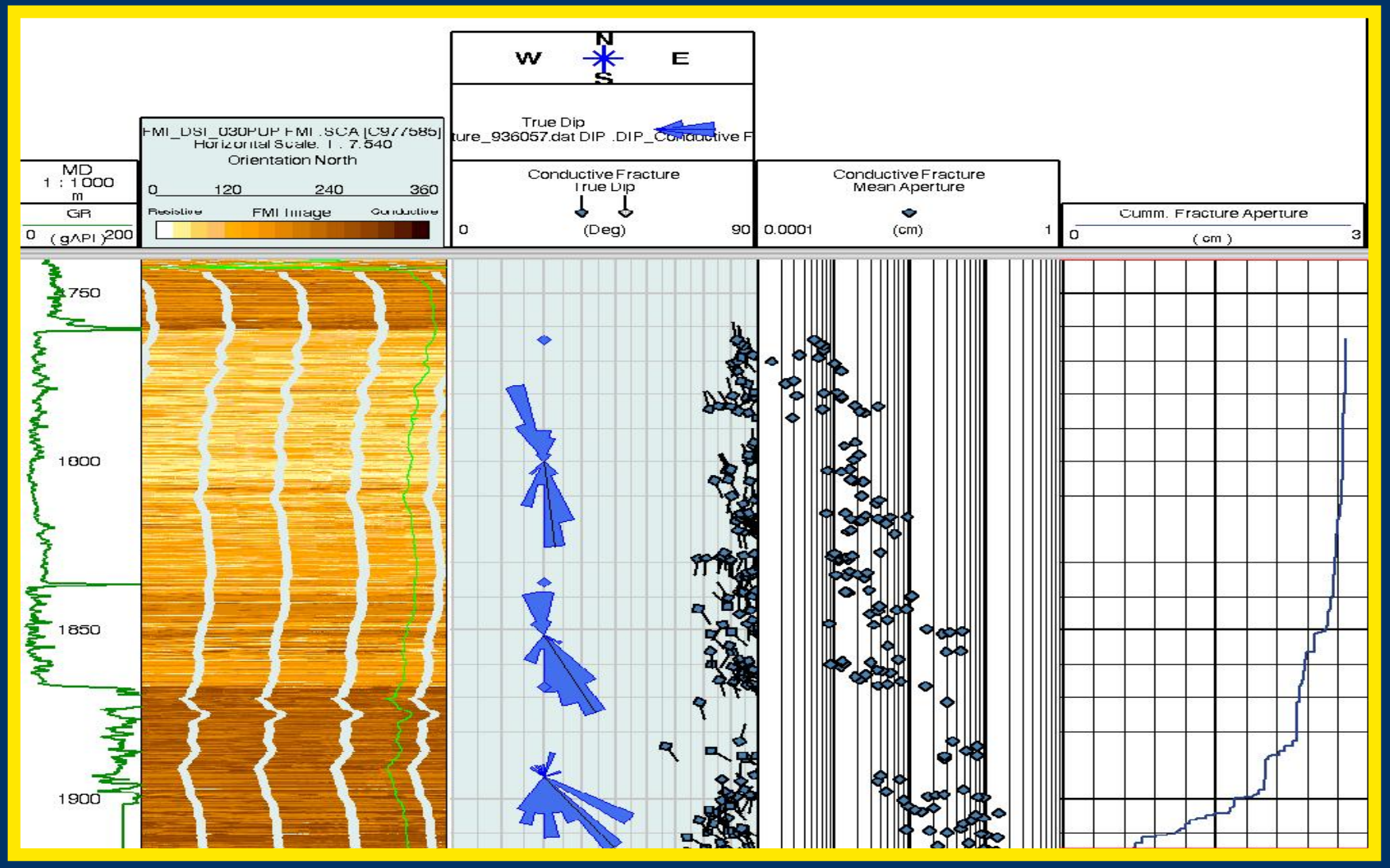
Estimation of angular relationship between present-day in-situ stress & open fractures

/from core material/

from APPLIED PALEOMAGNETICS, Inc., Santa Cruz, CA

BULGARTRANSGAZ

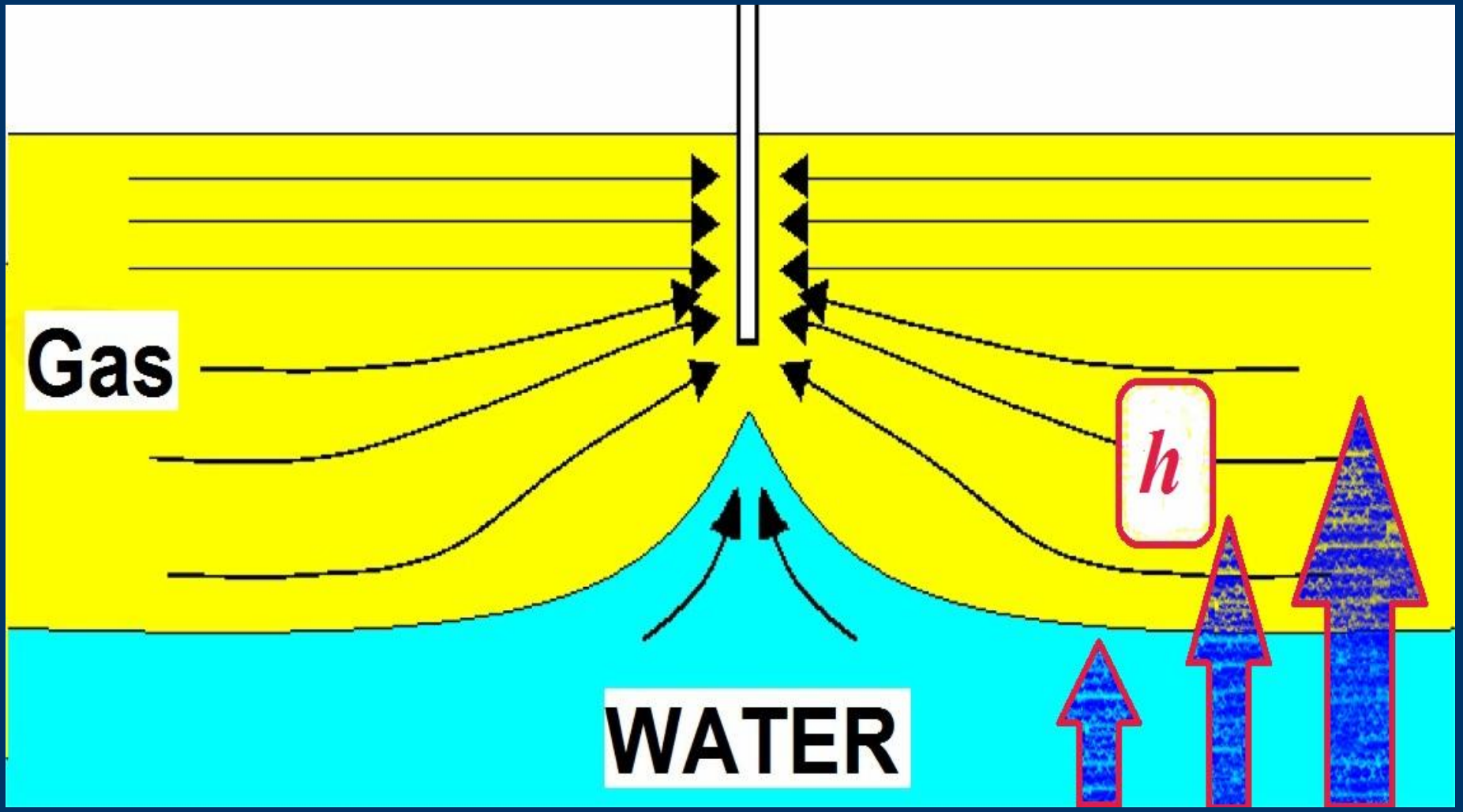
Fracture analysis using well-logging measurements



3-D view from FMI

BULGARTRANSGAZ

Water coning in fractured gas reservoir with bottom water



BULGARTRANSGAZ

New intensification approach based on the estimation of maximum depressions in the wells

- An **empirical formula** has been invented with sufficient accuracy for practical use;

- It is important to observe the **heights** of **water cones** towards the bottom perforation of the operational wells during withdrawal;

- The **daily rates** from UGS have been **increased** significantly.

BULGARTRANSGAZ

$$\Delta P_{max} = 0{,}052 \cdot h \cdot (\rho_{water} - \rho_{gas})$$

where,

ΔP max is the maximum depression in the wells for **dry regime of withdrawal**, (in psi);

ρ water is the water density (in lb/gal);

ρ gas is the gas density (in lb/gal);

h is the depth from the lowest perforation to the WGC (in feet).

ρ_{water} = 8.145 lb/gal ρ_{gas} = 0.651 lb/gal.

(Both densities are taken at max reservoir pressure of 115 bar and formation temperature of 72-73 C^0 for Chiren UGS gas storage reservoir).

BULGARTRANSGAZ

$$t_{max} = k \cdot h^2 / \Delta P_{max}$$

t max is the time in days at which the water cone reaches the bottom of the perforation but **the regime of withdrawal comtinues to be dry;**

h is the distance between the WGC and the lowest perforation of the operational well, in m;

ΔP max is the maximum depression of the well, in bar. **Dry regime of withdrawal is being kept**;

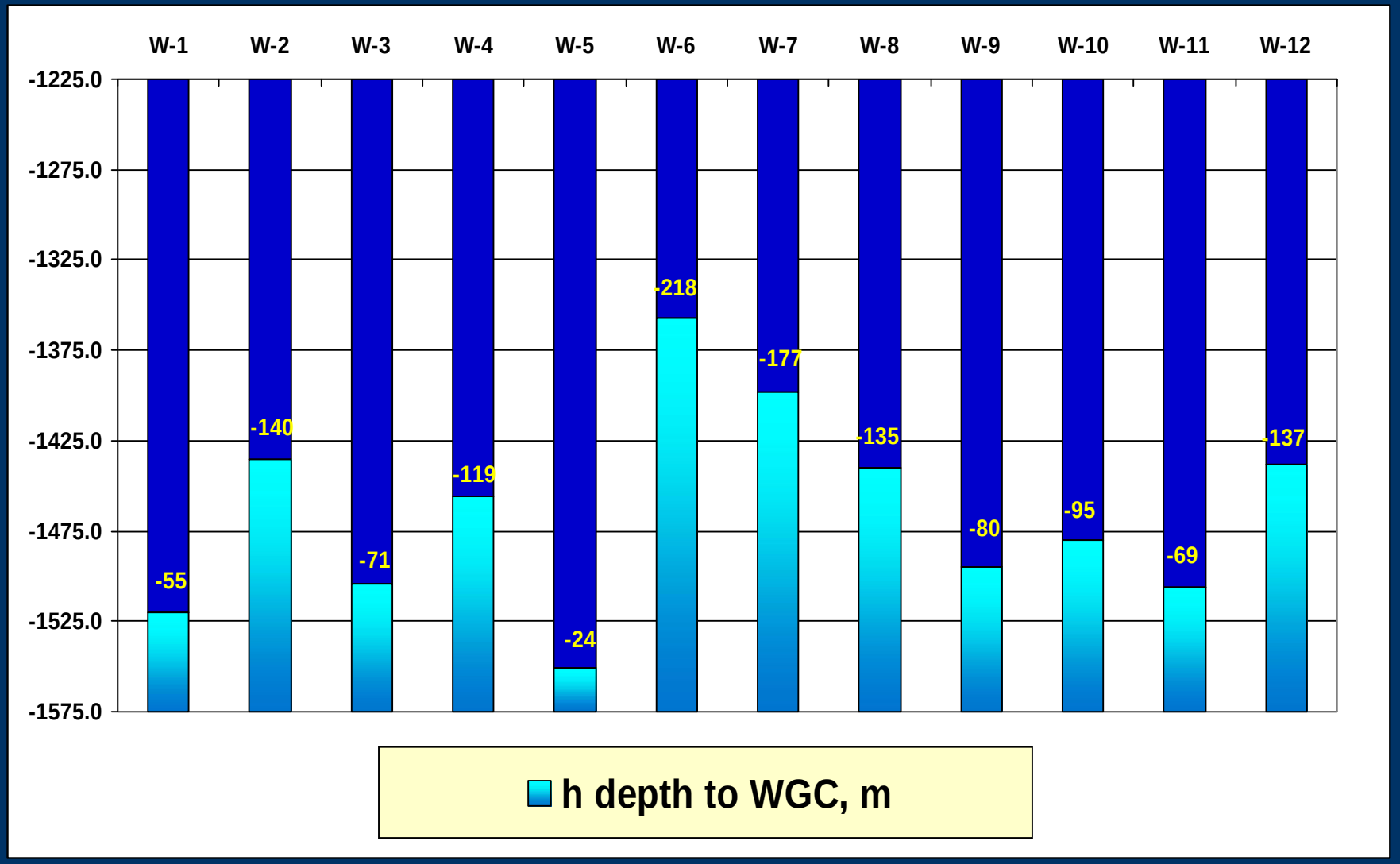
k is an **unique coefficient**, that depends on the gas bearing rocks, reservoir properties and friction interfacial forces. It is different for the different types of reservoirs and groups of wells. **For Chiren UGS case, this coefficient has been defined empirically.**

k = 0.06

BULGARTRANSGAZ

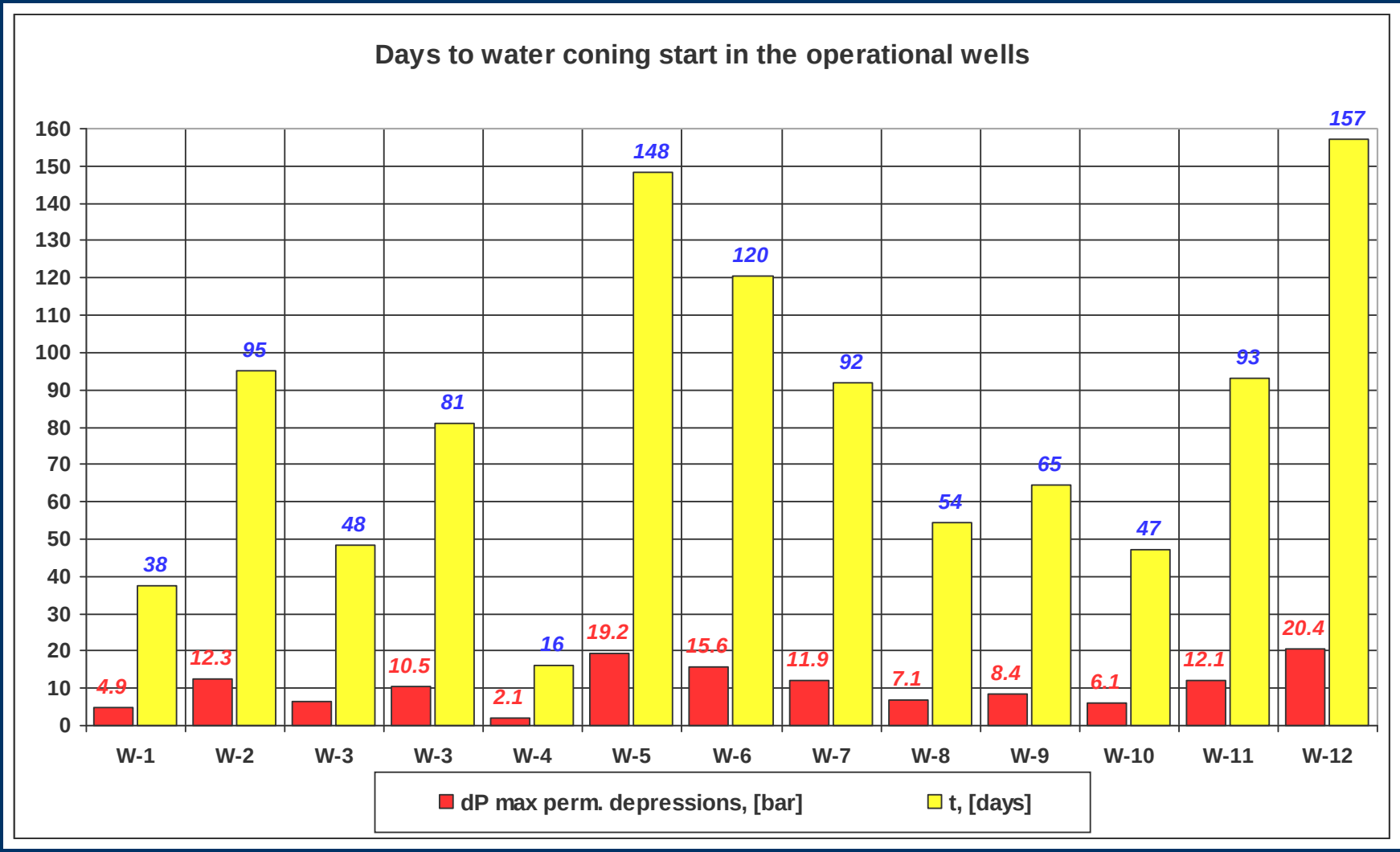
Wells	Elevation, [m]	TVD of lowest perforation, [m]	h, depth to WGC, [m]	ΔP max. [bar]	*t max, days*
W-1	355.3	1519.7	55.3	**4.9**	***38***
W-2	267.4	1435.0	140.0	**12.3**	***95***
W-3	262.6	1504.0	71.0	**6.3**	***48***
W-4	256.3	1456.0	119.0	**10.5**	***81***
W-5	259.0	1551.0	24.0	**2.1**	***16***
W-6	238.4	1357.0	218.0	**19.2**	***148***
W-7	261.5	1398.0	177.0	**15.6**	***120***
W-8	307.6	1440.0	135.0	**11.9**	***92***
W-9	292.0	1495.0	80.0	**7.1**	***54***
W-10	277.0	1480.0	95.0	**8.4**	***65***
W-11	298.6	1506.0	69.0	**6.1**	***47***
W-12	260.2	1438.0	137.0	**12.1**	***93***

Depths to the WGC of the operational wells



BULGARTRANSGAZ

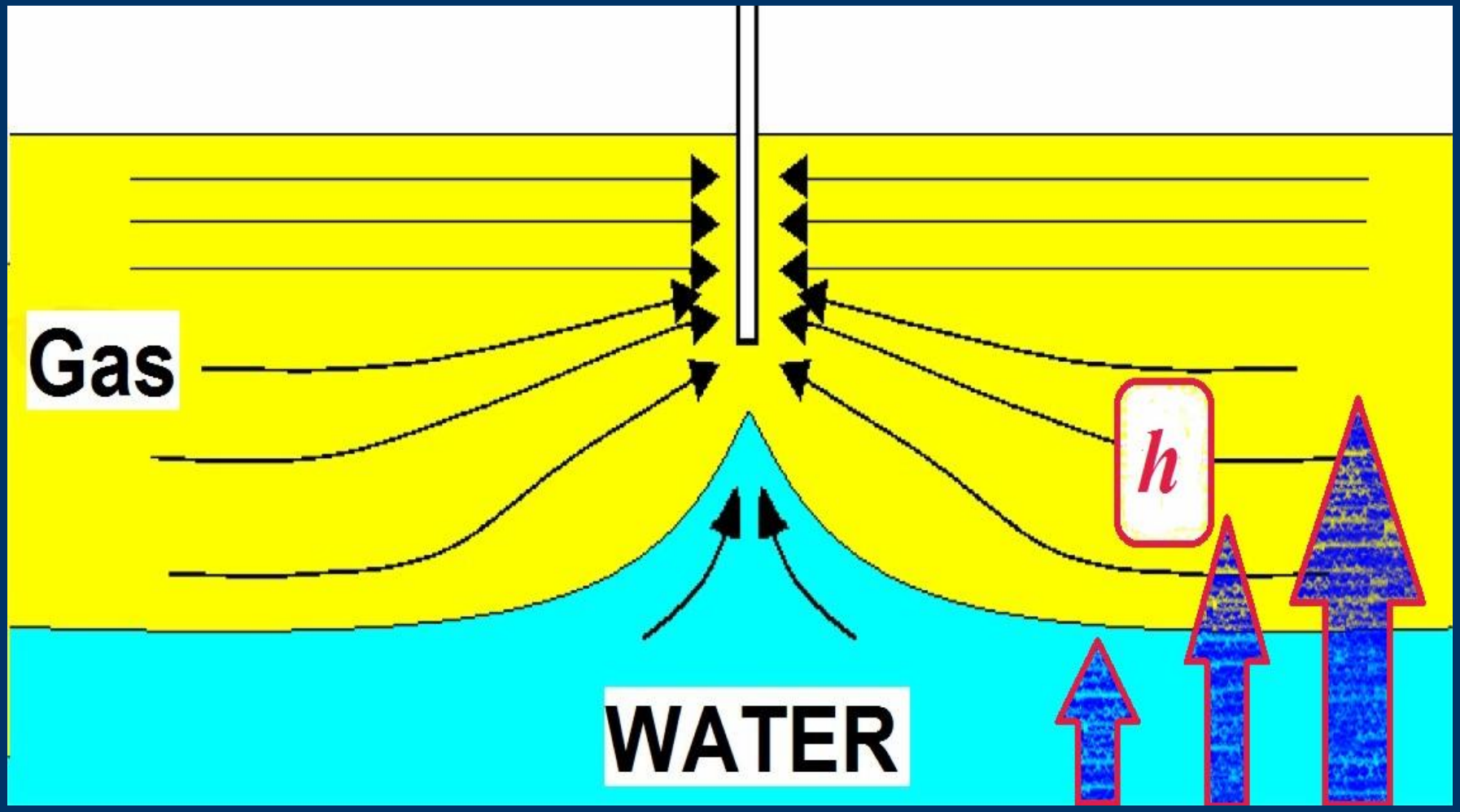
Dry or relatively dry mode of UGS operation… It is possible ?



BULGARTRANSGAZ

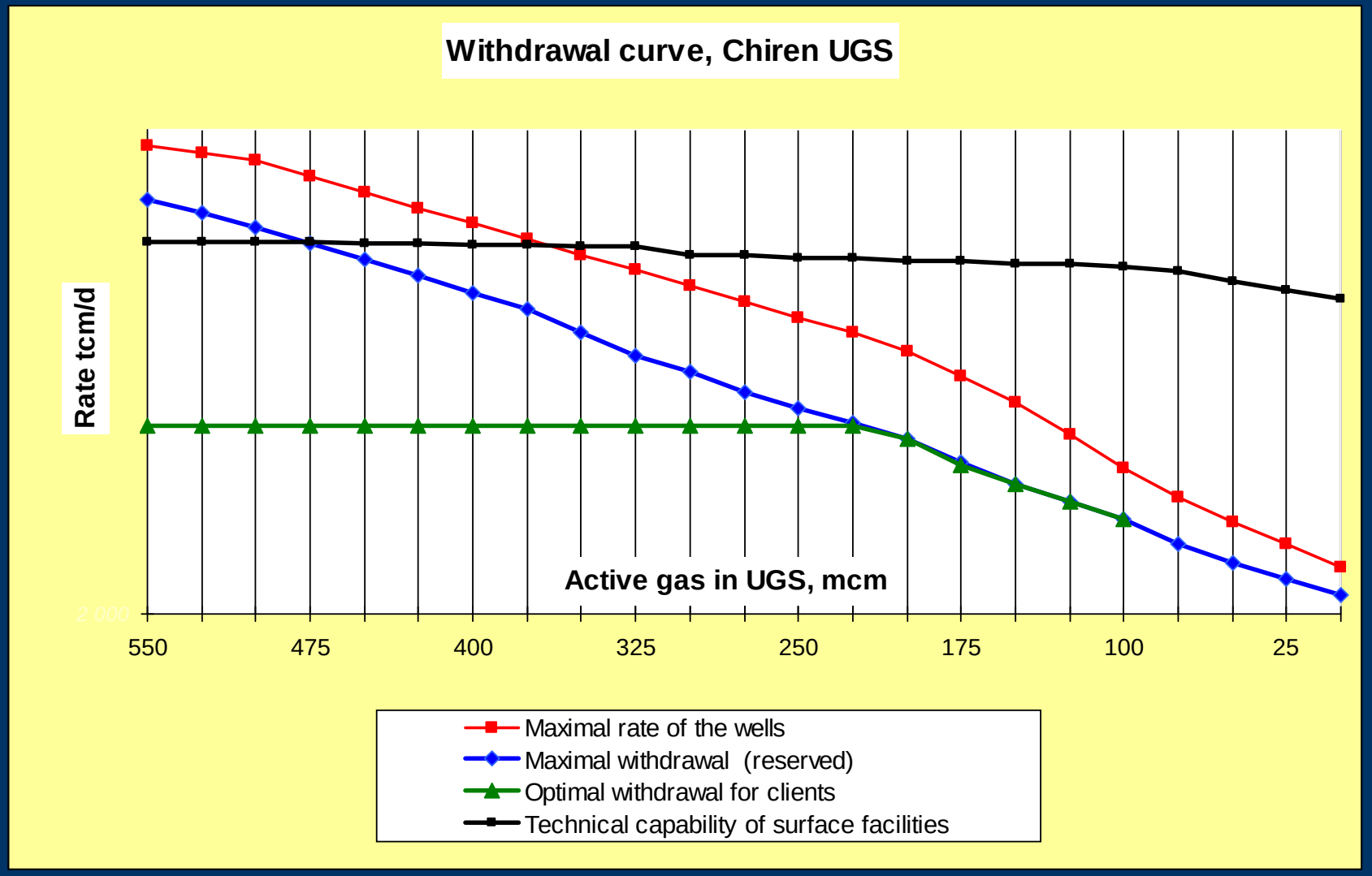
$$t_{max} = 0.06 \cdot h^2 / \Delta P_{max}$$

$$h_{current} = SQRT (t_{max} \cdot \Delta P_{current} / 0.06)$$



BULGARTRANSGAZ

Optimal and save withdrawal curve



BULGARTRANSGAZ

Conclusions:

- An useful **analytical method** has been exposed based on simplified method for computing;

- For practical purposes, an **empirical formula** has been invented with accuracy that is sufficient for practical use, which enables us to know the approximate height of the water cone versus withdrawal period;

- Having at disposal the **maximum permissible depression** of each well, the observation of water cone height vs. time affords us opportunity to utilize the withdrawal capacity of the gas storage in a most optimal and save way during the whole withdrawal period.

BULGARTRANSGAZ

Benefits:

- Creating an **optimal mode of operation**, hence safe withdrawal curve of the gas storage;

- **Flexible** gas storage operation (management) - preconditions for economic benefits for the company;

- **Optimal conditions for the next injection cycle** is being created – (avoidance of negative processes in the gas storage reservoir as trapping of gas in certain zones of the gas reservoir, etc.).

BULGARTRANSGAZ

Thank you.

BULGARTRANSGAZ