GROUNDWATER LEVEL DYNAMIC IN SALT DEPOSIT "TUSANJ" IN FUNCTION OF PREVENTING SHAFT STABILITY AGAINST CRITICAL HYDROSTATIC PRESSURE

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ABSTRACT

Rock salt exploitation from the salt deposit "Tusanj" in Tuzla dated already from the ancient times. Exploitation methods evolved as the time based from primitive one (natural salt springs) up to more contemporary. Three basic salt exploitation methods are used at the present:

-deep well pumping of natural mineralized brine (uncontrolled leaching method)

-underground exploitation of rock salt (classic mining method)

-natural water injection in deposit and brine pumping by the special wells (controlled leaching method)

All three methods are existing in parallel , although excluding each other in some way.

This paper deals with aligning uncontrolled leaching method with underground mining activities, altogether sanation activities on shaft lining aiming to match with hydrostatic pressure.

BASIC GEOLOGICAL AND HYDROGEOLOGICAL FEATURES OF SALT DEPOSIT

The rock salt deposit in Tuzla seen on the whole has a syncline form with the axis inclined to NW. Its area is 1.8 km^2 and is located at the northern part of the town Tuzla.

The deposit was formed by the chemical sedimentation in conditions of the lagoons, in Miocene period. Salt layers are interchanged with the interseams of marls, claystones, anhydrites and gypsum. In the salt deposit 5 saltseries are separated and marked as the series I, II, IIIB, IIIA and IV. They are located in banded marls, which are locally dolomitic.

Above the salt series are layers of marls, claystones and intercalation of sandstone (so called "slir") and in northern and northeastern deposit boundaries they are significantly represented by marly limestones, breccia, anhydrites know as "tuzlanski pločasti krečnjaci" (tuzla platy limestones). They play a significant role in the water inflow to the deposit.

Under the salt series are sandstones, alevrolites, marls, claystones and sandy limestones in so called "red series".

From hydrogeological aspects the layers in the roof above salt series (the slir) are low permeable in the primary state. But they, by secondary processes of the massifs degradation, due to the leaching show the characteristics of the media with fracture porosity. In the same way, the banded series (marls and claystones) inside of salt series are primarily impermeable, but because of salt leaching processes they get the characteristics of good permeable medium with fracture-carstic characteristics. The so called "red series" in the bottom of salt series have the characteristics of a hydrogeologic complex.

Expressively permeable are marly limestone layers on N and NE deposit boundaries and through them the water is infiltrated from the valleys of Solina and Jala rivers in to the salt deposit.

The infiltration in to deposit is in boundary zones and is dominant in the valleys region of Solina and Jala rivers on N and NE deposit boundaries. By pumping the brine in central deposit part, the infiltration on the peripheral zones is increased and the region of exploitation wells. The pumping for a long time, as the salt leaching from the productive series, destroy the roof seams and there is a complete fractured carstic zone formed. This zone is continually extended and has a hydraulic connection with the region of underground mining, what means with region of the hoisting and ventilating shafts (see Fig.2).

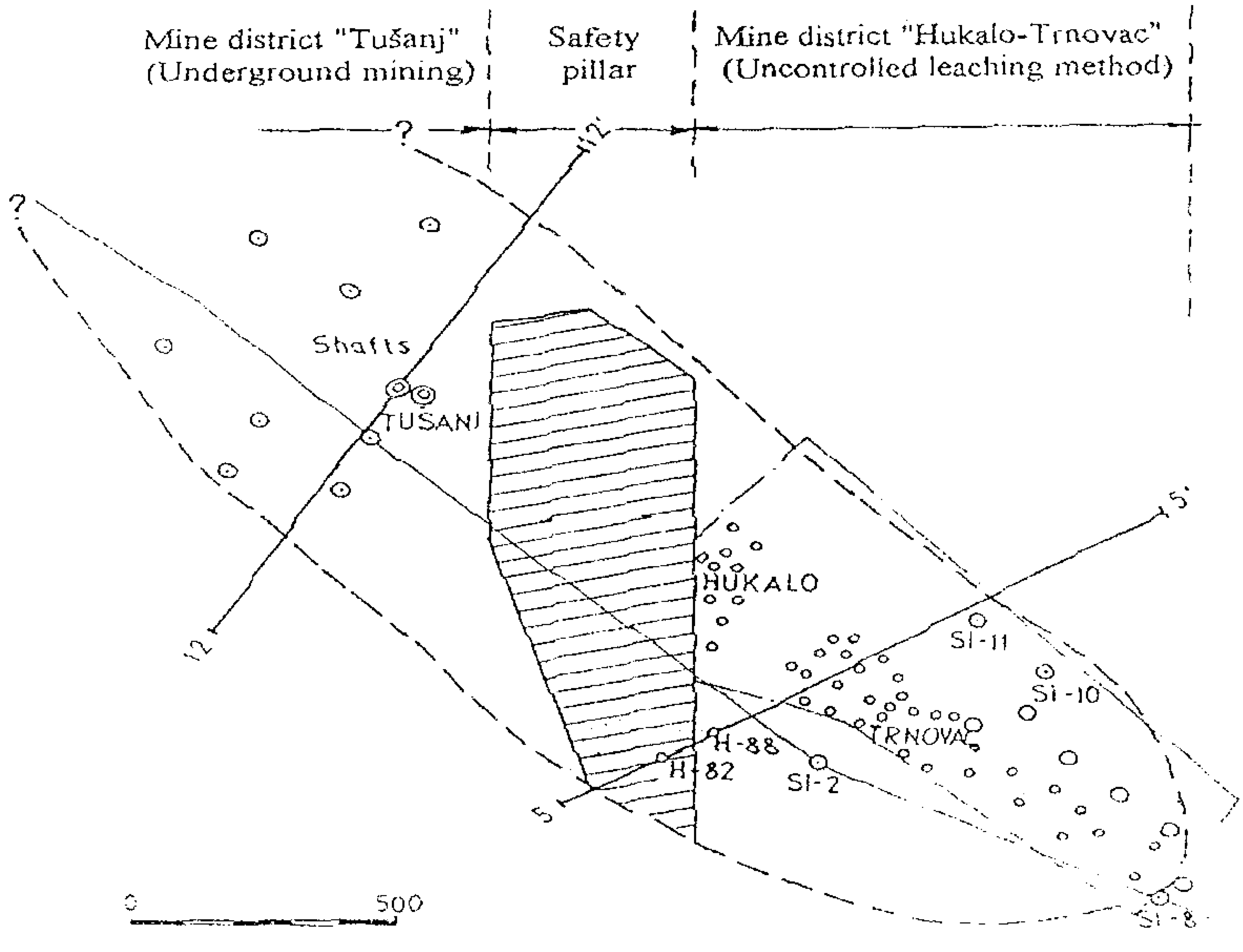

Fig. 1. ROCK SALT DEPOSIT IN TUZLA

BASIC FEATURES OF EXPLOITATION PROCESS

Current extracting of rock salt in this area is carried out by three methods (three different technologies)

- deep well pumping of natural mineralized brine (uncontrolled leaching method)
- underground exploitation of rock salt (classic mining method)
- natural water injection in deposit and brine pumping by the special wells and chambers (controlled leaching method)

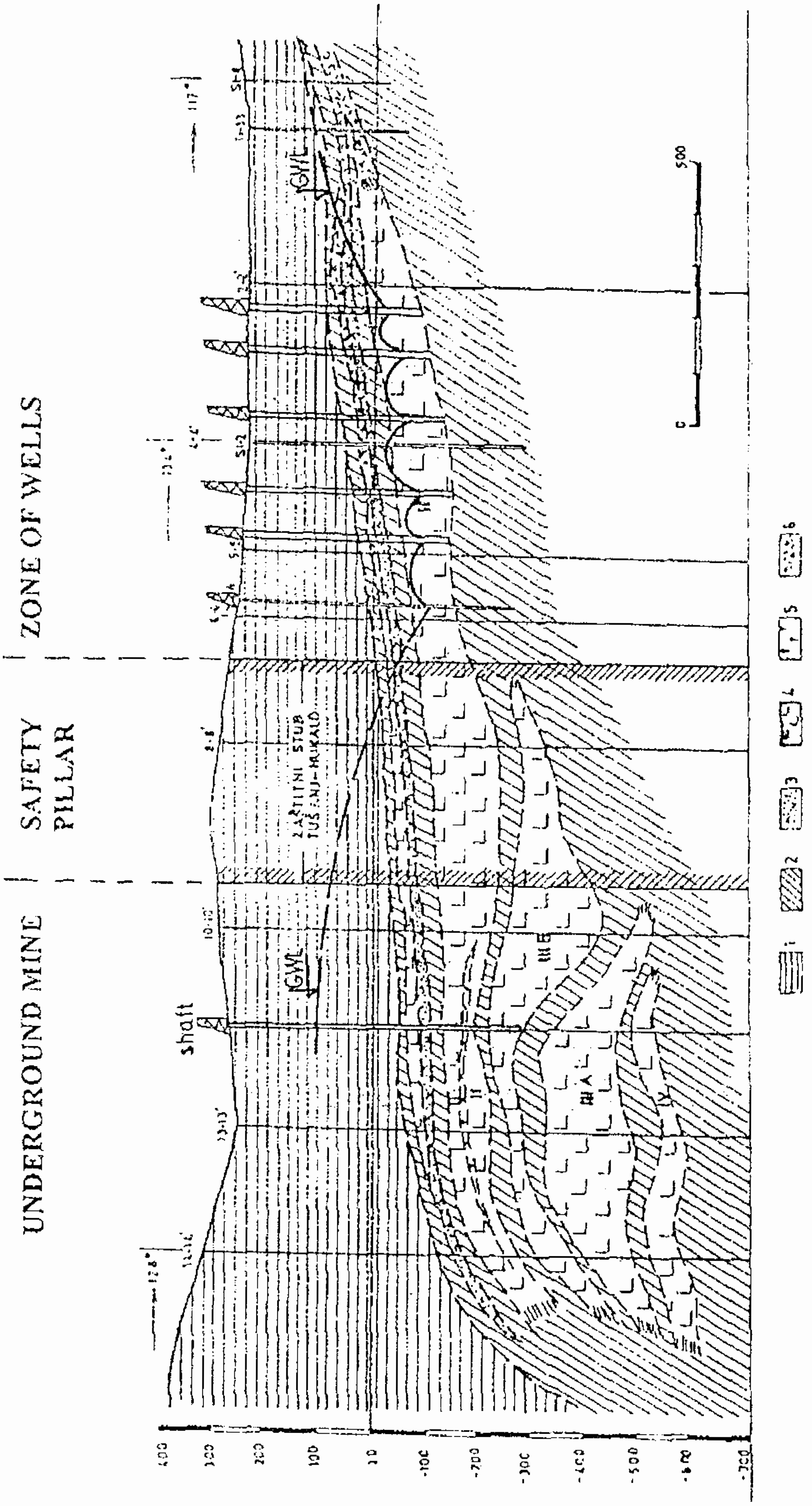

Fig 2. LONGITUDINAL HYDROGEOLOGICAL CROSS SECTION

1. Slir - HG insulator
2. Band marl - HG insulator - cloector option
3. Pelit - HG insulator - colector option
4. Salt
5. Anhydrite - HG insulator
6. Peripheral leaching products - HG colector

Uncontrolled leaching method (brine pumping) the oldest one, applied in south-east part of deposit. (see Fig .1)

This method is based on pumping mineralized, formed by peripheral fresh water inflow, salt layers dissolution and established fracture-carstic type ground water. Intense pumping of brine implies forced underground water level drop and increased volume of salt extracted from deposit. Intense salt deposit destruction and huge scale surface terrain subsidence is the consequence of this process. The most important consequences are:

-ground (surface) subsidence on about 5000 000 m^2, with vertical component more than 12 m and maximal annual magnitude from 1,1 m,

-extraction (leaching) of solid salt, saltwater pumping and continuous drop of level during a long period of time, resulted in a dynamic surface sinking process (subsidence),

-due to the surface deformation, 2700 flats, 67000 m^2 business area, 131 000 m^2 public objects have been knocked down, including many kilometers of infrastructural objects,

-about 15 000 inhabitants have been relocated from the endangered area,

-Tuzla town does not have the normal urban development, because the priority is to substitute the destroyed buildings.

Regarding the consequences to city urban area, this process is might be considered as "ecological bomb".

Underground rock salt exploitation is developed in north-west part of deposit and separated by so called safety pillar (barrier) from uncontrolled leaching area. However, the fractured-carstic groundwater extends also in this area, revealed already during the construction of opening shafts. In course of shafts boring throughout water saturated roof wall layers, special methods (freezing) where applied with special shaft construction enabling waterproof construction during shaft exploitation. In this way, upper water saturated layers where isolated from deep underground mining facilities by constructing very complex yet flexible shaft lining, regarding to be the exclusive condition of mine existence.

SHAFT CONSTRUCTION FEATURES AT OUT HYDROSTATIC PRESSURE ASPECT

Numerous factors of surrounding rock and shaft construction and functional efficiency of shaft lining. One of those is hydrostatic pressure imposed on shaft lining. The intensity of hydrostatic pressure in shaft area is directly connected with pumping intensity from the wells in neighbor region. Regarding the limiting nature of physical and mechanical features of shaft lining, and is definited by the critical hydrostatic pressure determined with brine pumping intensity.

The shaft lining construction is designed basically for the regular work conditions and is realized in one part as a classical walled lining in concrete blocks (in unwatered zone - unhermetically) and in other part is realized as a construction with tubings (in watered zone - watertight). The tubing lining is wade as "relatively Bentley tube" composed of cast iron rings consisting of 8 sections, among them tied with bolts and lead gaskets. This lining is made in more sections (total length ~ 120 m) and intersectional contacts are tightened witht he pressed wood. On this way a complete water tightness is secured and the oscillation of underground waters in fractured carstic zone directly reflects the change in hydrostatic pressure on lining.

Vertical and horizontal massif movements due to the salt leaching process have created one irregular distribution of the loads and forces, so the lining suffered the deformations of the shortening and curving of the tubings ($\varepsilon_{pr} > 2,6$ mm / m). Permissible deformations (contraction of the tubing lining may be (to some germane and polish authors) max. to 50 % wood or lead gasket height and to 0,5 ‰ of cast iron segments length.

A sanation of the shaft lining supposes the following
- to restore water tightness
- to adapt the lining to massif movement and the maximal elasticity

These conditions had to be met by a special construction of two column steel cylindrical casing in a length of 60 m (the length of damaged primary lining) with the foot in the stable tubing zone and the tap ended with a special telescopic construction. The telescopic construction should compensate the vertical massif movement. Double ring interspace was filled with concrete (the inner one) and with the asphalt (the outer one) what had to secure the water tightness. During the sanation works a dramatic situations happened with a waterinrush and the planed solution was reduced to fulfill annulus with the concrete instead with the asphalt. This changed the idea of the project because through the concrete ring in the construction is introduced the axial force and the conditions for with at is not designed and faced with the destruction, and a special compensator was introduced which is the weakest point in all construction. That was very soon, because the vertical massif movements have overcome the compensator possibilities and the building of a new foot and a new compensator was necessiated (see Fig.3).

This short overview of sanation work on the shaft lining indicates on the massif movement presence as on the water presence in fractured-carstic zone.

INFLUENCE OF THE UNDERGROUND WATER LEVEL ON THE SHAFT STABILITY

The problem of hydrostatic pressure on the shaft lining in the period of intensive brine pumping by wells was less expressed, because the water level was very low (abs. 30-40 m above sea level). Meanwhile when the uncontrolled brine production was reduced the underground water level increased as in the deposit so also in the hoisting shaft zone (see Fig. 4). From that time is a continuous effort how to keep the water tightness and shaft stability and to compensate by brine pumping the water level in the shaft zone.

Some analysis are made on permissible hydrostatic pressure (underground water level) on critical points of the lining and a system of monitoring the pressure on the lining. In 1985 at the water level hat 68 m asl, a hydrostatic pressure at 0,45 MPa was registered in telescope zone (so of the brine is 1,04 t/m^3. At groundwater level at 80 m asl. (1991) a hydrostatic pressure of 0,58 MPa behind the telescope was registered. A further in crease in the water level induces also an increase in hydrostatic pressure at the telescope level how it is shown in table below.

Table 1 :

Underground water level asl.	68	80	90	100	110	120
P (MPa)	0,45	1,58	0,68	0,79	0,9	1,01
Pressure increase %	100	130	151	176	200	224

SHEMATIC DISPLAY OF SHAFT LINING SANATION PER PHASES

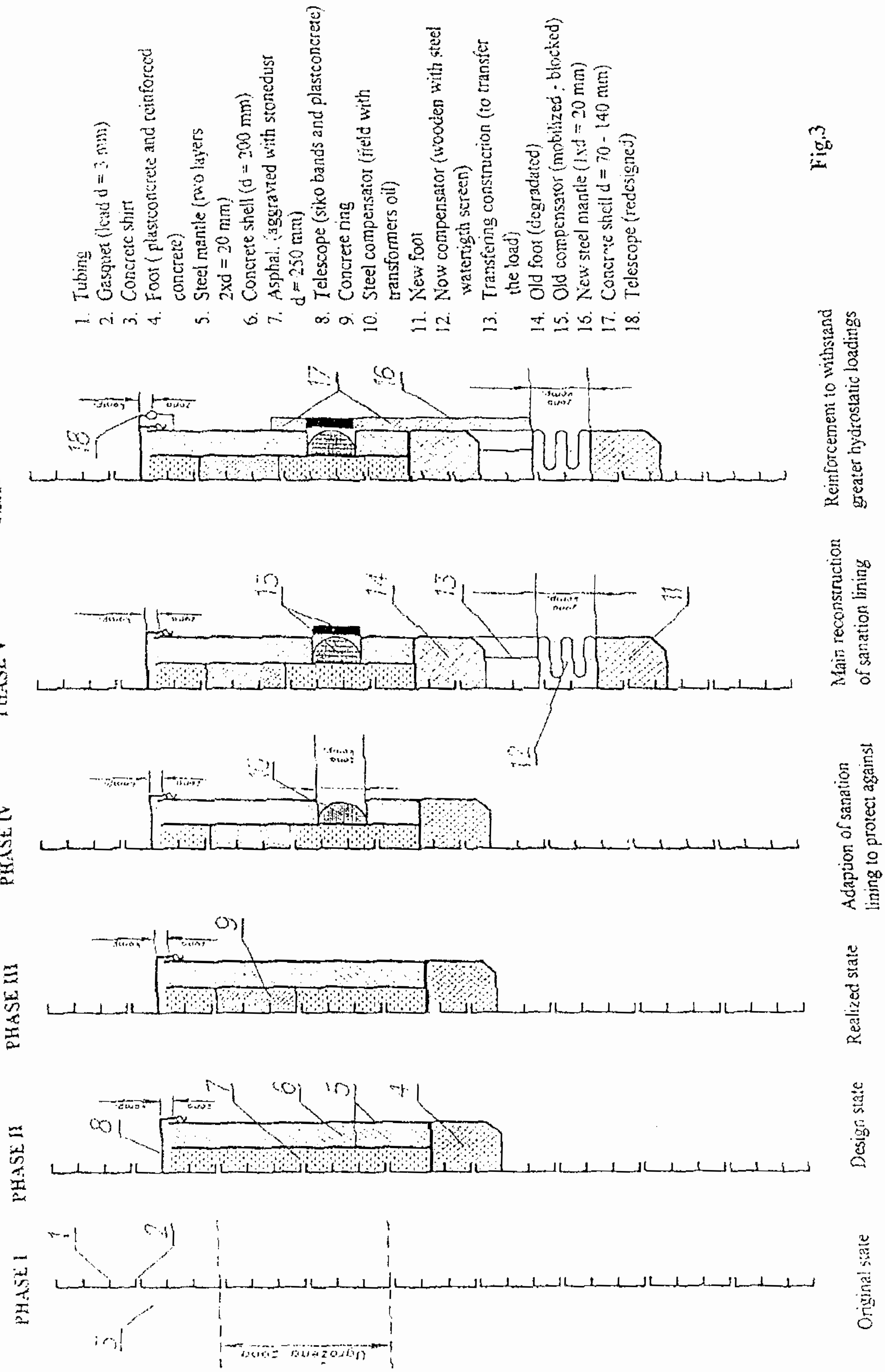

Fig.3

The second weak point in the construction (weakest) is in the element of the old compensator blockade. For this point was also determined an permissible underground water level (hydrostatic pressure) in the shaft zone.

$$GWL_{max.} = \frac{\sigma_{max.}}{\gamma_{br}} - 15 = \frac{1{,}2\ MPa}{0{,}01065} - 15 = +97\ m$$

Where is :

$\sigma_{max.}$ - Maximal permissible pressure on this part of the construction

γ_{br} - Average value for the brine specific mass

Additional - 15 m is taken as a guarantee for eventual necessary measures to reinforce this element it this critical level be reached.

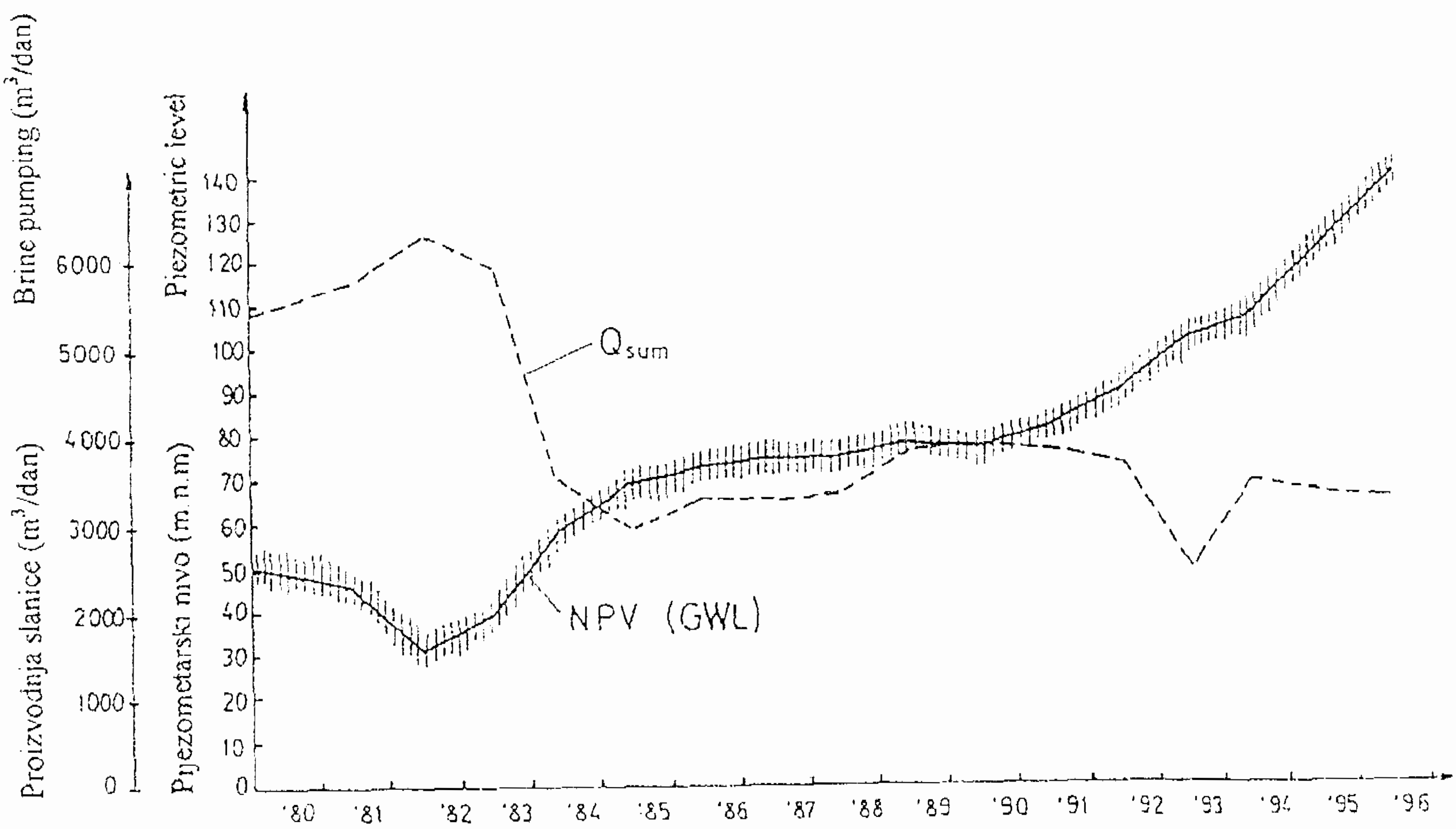

Fig.4 - DIJAGRAM CRPLJENJA SLANICE I PROSJEČNOG NPV U LEŽIŠTU
DIAGRAM OF BRINE PUMPING (Qsum) AND AVERAGE GROUNDWATER LEVEL (GWL) IN SALT DEPOSIT

Regarding the actual state of additional lining in the shaft it is permissible to allow the pressure to 140 m asl. and because actual level has reached the limit level it is to conclude that the shaft lining has no reserves in stability or they are minimal.

From all given above it is clear that the hydrostatic pressure presents a key factor for the shaft lining stability and controlling it is in a direct function of pumping intensity in the region of the uncontrolled production relativity of producing wells.

At reduced pumping intensity constatly increases underground water level and in last five years (the war in B&H) it reached the critical limit. The brine consumption is almost stopped (salt factory, soda factory, chemical complex) but the wells pumping should not be stopped because it is necessary to keep water level under the critical limit. In this situation a special attention is paid to the monitoring and coordination of the wells operations to maintain the shaft stability and not unnecessarily to pump the brine how to reduce the consequences of salt leaching.

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