Geogr. Fis. Dinam. Quat.
Suppl. VII (2005), 137-143, 9 figg., 2 tabb.

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THE NATURAL AND MAN-INDUCED SUBSIDENCE OF THE RAVENNA AREA (Po Plain)

ABSTRACT: ELMI C., BERTONI W. & MARABINI F., *The natural and man-induced subsidence of the Ravenna area, Po Plain.* (IT ISSN 1724-4757, 2005).

The Ravenna area (south-east rim of the Po Plain, Italy) is subject to a high regional natural subsidence, near to the maximum values of all the Po Plain, active from at least the Lower Pliocene and during all the Quaternary. In the last decades Ravenna and its surroundings have been affected by a man-induced subsidence of up to fifty times the natural rate, mainly due to water pumping and to the extraction of methane. Since the 1960's the progressively widening of the land sinking has influenced the whole historical centre and the new industrial zones, as well as the coastline, few kilometers from the city centre. The subsidence reached peaks of high risk and the related effects became critical. The progressive reduction in the last two decades of underground water use brought the subsidence close to natural rates, but the negative consequences of elevation loss in the near future due to coastal erosion, higher storm surges and the risk of river floods, still remain.

KEY WORDS: Subsidence, Piezometric decline, Coast erosion, Ravenna, Po Plain (Italy).

RIASSUNTO: ELMI C., BERTONI W. & MARABINI F., *Subsidenza naturale e artificiale nel Ravennate.* (IT ISSN 1724-4757, 2005).

L'area di Ravenna è soggetta ad una elevata subsidenza naturale prossima ai massimi valori registrati in tutta la Pianura Padana, attiva a partire almeno dal Pliocene inferiore e perdurante per tutto il Quaternario. Negli ultimi decenni, Ravenna e i suoi dintorni sono stati interessati da subsidenza artificiale con tassi fino a cinquanta volte quelli naturali, dovuti a pompaggio di acque dolci superficiali e in minore misura a estrazione di metano da *reservoirs* più profondi. A partire dal 1960 il progressivo ampliamento del fenomeno ha coinvolto l'intero centro storico e la vicina zona industriale, e così pure la fascia costiera, a pochi km dalla città, con punte di elevato rischio. La progressiva riduzione dei pompaggi dagli acquiferi superficiali ha portato la velocità di subsidenza a valori prossimi a quelli naturali, ma restano le conseguenze negative della perdita di quota, prossima a circa 1 m, ossia erosione costiera, ingresso di acque alte e rischio di esondazioni dei corsi d'acqua.

TERMINI CHIAVE: Subsidenza, Idrogeologia, Erosione costiera, Ravenna, Pianura Padana.

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Grants supported by University of Bologna, funds ex 60% 2003-2004, Scientific Resp. C. Elmi.

INTRODUCTION: THE NATURAL SUBSIDENCE

The Po Plain forms a complex system where tectonic, depositional, climatic and man-induced factors act in ways that are different in intensity and velocity, with superimposed effects. The so called «Po Valley» is clearly shaped by the tectonic activity, dating back at least to Lower Miocene. The tectonic effects of compressive deformations, subsidence and local uplift, show high variability in space: the subsidence varies in small cells of 1 to 50 km in dimension. On the other hand, the deformation rates in the single cells are quite constant or slowly changing during the whole Quaternary at least.

The causes of the natural subsidence are: a) crust deformations; b) sediment compaction; c) isostatic response to the variation of load, i.e. sediment and marine water load; d) eustatic sea level rise (relative subsidence) (Bosi & *alii*, 1996). If a continuous accumulation in a shallow marine basin similar to the present Adriatic Sea is assumed, the natural subsidence may be indirectly inferred by the sediment thickness. If there is no need to know the uncompacted thickness of the various stratigraphic units, and «if we are satisfied with a global evaluation through geological periods, we can use the compacted thickness of the various formations, as they may be derived from the chronostratigraphic reconstruction» (Gambolati & Teatini, 1997).

Therefore, knowing the thickness, the time (duration) of deposition and the variation of deposition depth, it is possible: a) to distinguish areas of different subsidence, and b) to obtain the approximate subsidence-sedimentation rates or velocity V. This is expressed by:

$$V = (S_{tot} - \Delta_z)/T \neq 0 \qquad (1)$$

where

S_{tot} = total subsidence (defined by sediment thickness), due to tectonic sinking, to sediment compaction and to isostatic response;