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Biogenic/Abiogenic Hydrocarbons Origin

Possible Role of Tectonically Active Belts

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Abstract. The creation of hydrocarbons is linked to tectono-geologic processes and particularly to orogenesis, rifting, overthrusts, erosion, deposition of sediments, deep gas emissions, etc.. Many have claimed the inadequacy of plate tectonics in linearly explain a number of phenomena involved in hydrocarbons generation and geological processes, and many others have defended the synthesis of hydrocarbons starting from inorganic minerals, proposing different geochemical processes. In this paper a possible mechanism for production of abiogenic hydrocarbons is proposed, linking it to a previously proposed orogenic isostatic model. While in plate tectonics the cold slab travels in contact with the lithosphere of the continental side, oxidizing materials faced to oxidizing materials, in this model the high-temperature reducing environment of the undepleted mantle rises up and come in contact with the relatively cold oxidizing lithospheric environment. Non-lithostatic overpressures and a number of chemical reactions are then favoured in this sort of tectonic oxidizing-reducing pile, leading to a multiple origin of the hydrocarbons. The actual situation along the Italian Apennines orogenic belt seems in accord to the proposed model in which an important role should have the abiogenic hydrocarbons in particular those produced by the tectonic working at the western margin of the Adriatic plate. However, albeit a continuous accumulation of abiogenic hydrocarbons is witnessed by a number of planetary bodies of the Solar system, still no evaluation of the abiogenic/biogenic hydrocarbons rate is possible on our planet.

Key words. Abiogenic hydrocarbons – Origin of hydrocarbons – Earth's expansion and degassing – Nonlithostatic overpressures – Italian oil and gas

1. Introduction

It is nearly obvious that the creation of hydrocarbons is linked to tectono-geologic processes and particularly to orogenesis. Rifting, overthrusts, erosion, deposition of sediments, deep gas emissions, etc. can contribute to the burial and to the metamorphosis of the biogenic and/or abiogenic materials into hydrocarbons. But this connection with orogenesis should be expected to be different in the case of different global-tectonics theories. Indeed, isolated voices have claimed the inadequacy of plate tectonics in linearly explain a number of phenomena involved in hydrocarbons generation (Pratsch, 1978) and geological processes (Hilgenberg, 1974; Carey, 1975; Chudinov, 2001, part 3, on ore deposits; Scalera, 2006, 2007ab, 2008; Maxlow, 2012, this book).

Superimposed to this uncertainty in the effectiveness of the current global tectonics scheme, the second major field of debates is the biogenic or abiogenic origin of petroleum, or eventually the possibility of a mixing of the two generation processes (Colombo, 1972; Dmitrievskii, 2008).

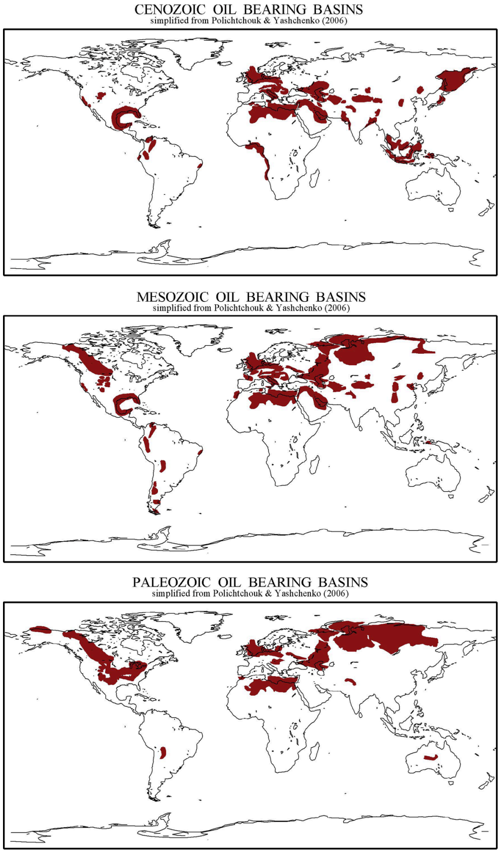

Fig. 1. The relation between the distribution of hydrocarbons and their age. Upper Map: Distribution of Cenozoic oil-bearing basins. Central Map: Distribution of Mesozoic oil-bearing basins. Lower Map: Distribution of Palaeozoic oil-bearing basins. Redrawn and simplified from Polichtchouk & Yashchenko, 2006.

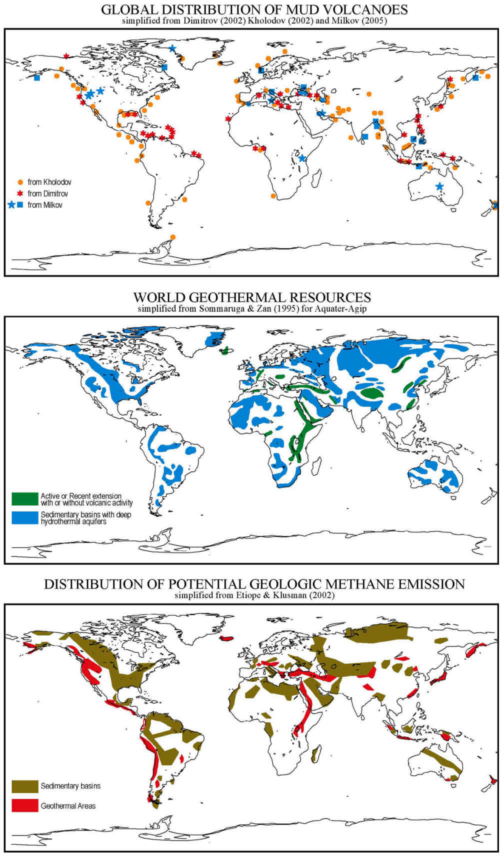

Fig. 2. The relation among the distribution of hydrocarbons and others tectonically related features. Upper Map: Distribution of mud volcanoes, drawn integrating maps of Dimitrov (2002), Kholodov (2002), Milkov (2005). Middle Map: Geothermal resources of the world, redrawn and simplified from Summaruga & Zan (1995), in which recent rifting and hydrothermal aquifers are shown. Lower Map: Potential geologic methane emission regions, redrawn from Etiope & Klusman (2002). Mud volcanoes have a good fit with the Cenozoic Oil Bearing Basins. This is clue that, where mud volcanoes are present, but no oil fields are mapped, the region should be better explored (e.g. the southern tip of India). Low energy geothermal aquifers (blu areas in Sommaruga & Zan) can be associated to oil field, while the high energy Recent extensional regions (green areas in Sommaruga & Zan and red areas in Etiope & Klusman) generally are not concomitant with oil. This evidence is in agreement to the new proposed model because the initial extensional phases cannot produce deep or shallow suitable conditions to hydrocarbons formation.

Historically, the abiogenic hypothesis on the petroleum' origin is very old. Mendeleyev (1834-1907), Berthelot (1827-1907), Vernadsky (1863-1945), Kudryavtsev (1898-1971), Porfir'ev (1899-1982), and many others defended the synthesis of hydrocarbons starting from inorganic minerals, proposing different geochemical processes (Dott & Reynolds, 1969).

Because the enormous strategic and economic importance of the hydrocarbons extraction and exploitation, western researchers involved in petroleum geology have considered with great caution the claims of success of the abiogenic theory followers. They have been afraid to abandon the traditional field investigation methods, because scared by the negative consequences and the damages on western economy if the new method of survey turns out as unreliable. Today the situation is still largely unresolved. Progressively, more numerous are becoming the evidence supporting the abiogenic origin of many compounds that are found in the oil reservoirs and elsewhere, and the western geologists today are admitting that some oil fields are of abiogenic nature (Horita & Berndt, 1999; Fiebig et al., 2004; Kitchka, 2004; Sherwood Lollar et al., 2006; Fiebig et al., 2007; Sherwood Lollar et al., 2008; and many others). The undeniable copresence of both biogenic and abiogenic signatures – in various rates – in most hydrocarbons fields, should be considered the true important clue in defining new models of gas and oil formation or in choosing among the existing ones. In the following pages I will try to assess the degree of validity of a recently proposed model of fold belt evolution, and if it is in agreement – and in what limits – with the observed phenomenons.

2. Biogenic and abiogenic field evidence

The biogenic theory is corroborated by many biomarkers (e.g. oleanane linked to angiosperms) with undoubted link to the flora that existed in that geologic epoch (Mello & Moldowan, 2005) and to the actual deposition into sediments of air dispersed organic volatile materials or of buried plants (Brooks, 1948; Hobson & Tiratsoo, 1975; among others) and remnants of animal life. Many types of oils are indicative of a rapid deposition of an organic source material into subsiding basins, and this is in accord with geologic evidence. Evidence are also clear that a number of complex substances in the petroleum have a thermo-labile behaviour that never experienced high temperatures. The depletion of ^{13}C in the oil fields and in the diamondoids is considered a further evidence because the chlorophyll cycle favour the preservation of ^{12}C (but different explanations are possible).

Some isotopic markers are of clear abiogenic origin, and especially the presence of Helium reveals a deep origin of the material flux. Also some enrichment and depletion in isotopic species are considered clues of a deep and then of abiogenic origin.

Many findings of abiogenic methane and HCs have been reported in association to serpentinised rocks (Szatmari et al., 2005; Sachan et al., 2007) and to other geological environments (Horita & Berndt, 1999; Fiebig et al., 2004; Sherwood Lollar et al., 2006; Fiebig et al., 2007; Sherwood Lollar et al., 2008). Experimental evidence that HCs can be naturally produced by abiotic chemical reactions is growing (Giardini & Melton, 1981; Scott et al., 2004; Martinelli & Plescia, 2005).

The old and main critique (frequently discussed starting from the second half of 19th century; Brooks, 1948) of the followers of inorganic origin of petroleum is that the temperatures evaluated from the geologic history of many reservoirs was not sufficient to the process of oil distillation envisaged by the first biogenic conceptions. Many other arguments and factual data about the abiogenic origin can be found in Hedberg (1969), Porfir'ev (1974), Glasby (2006), Katz et al. (2008).

3. The theory of Thomas Gold

The astrophysicist Thomas Gold wrote in the years seventieth a series of papers about the role of a possible ascent of mantle fluids in producing – under some conditions – hydrocarbons and oil. The earthquakes play a special role in Gold's ideas, because the rise of fluids can be made easier – and possible – by the fractures induced by earthquakes into the crust and lithosphere. Gold & Soter (1980) compiled a map of the correlation between oil fields and earthquake-prone belts (today and in the geological past), in which was highlighted the presence of both the phenomena in common zones.

The Thomas Gold theory about the deep origin of the HCs hypothesised a depth from 100 to 300 km for the formation of simplest HCs like methane (Gold. 2001). These compounds acquire their apparent organic origin by contamination and by interaction with the deep microbial life during the last ten km of their migration towards the crust. The real presence of a deep microbial habitat is today an ascertained fact (Pedersen K., 2000; Schulze-Makuch & Irwin, 2004; Head et al., 2003). Albeit the Gold's estimation of the amount of the mass of carbon linked to subsurface life was too exaggerated (Gold, 1992), the recent estimate reach a value of 325 – 518 $\times$ 10^{15} g, nearly equal to the value (561 $\times$ 10^{15} g) of the sum of dry-land and marine life (Fyfe, 1996; Whitman et al., 1998). Finally, the presence of helium – a primordial mantle element – in the HCs fields was judged by Gold as an evidence in favour of the deep origin of petroleum.

Many criticisms to the Gold's model have been advanced (Glasby, 2006). Among these, the main problems are: that the transformation of methane to higher HCs is not possible at depth above 100 km (see the Kenney's theory on the thermodynamic impossibility of this, 2002) and that the bacteria in the upper crust cannot overcome the energetic impossibility because they eat to get and not to dissipate energy. The $^3H/^4H$ rate was required to be low in Gold conceptions, because a sort of washing away operated by the methane flow, but a higher than normal $^3H/^4H$ was observed in the HCs fields. Many other criticisms can be read in the book-review of Peters (1999) and in Laherrere (2004) and Pfeiffer (2005).

All the preceding arguments have made partially invalid the Gold's mechanism for oil formation, albeit his more general view of a slow expulsion of hydrocarbons from the interior of the planets has been confirmed by the presence of methane on several Solar System orbiting bodies (Cruikshank & Apt, 1984; Spencer et al., 1990; Lunine et al., 1999; Hand, 2008; Mumma et al., 2009; among others). Hydrocarbons are contained in carbonaceous chondrite meteorites and a large amount of methane and hydrocarbons has been detected on the surface of Titan (Saturn's moon) where biological remains of a surface life cannot exist (Lunine et al., 1998; Lunine et al., 1999; among others). Recently definitive evidence of methane emissions on the highlands of Mars has been found (Hand, 2008; Mumma et al., 2009).

My personal criticisms are:

i) Gold does not envisage different geodynamical scenarios with respect to plate tectonics. He assumes the subduction as a real ongoing geological-physical phenomenon. This is the reason why:

ii) he cannot be aware both of the exiguity of the role he assigned to the seismic events and of:

iii) the important information provided by the unsuccessful experiment of the deep borehole in the old (≈360 My, the Siljan Ring) impact crater in Sweden (Gold, 1987, 1991, 1993; but he firmly maintains that oil was found).

I will show that the three weaknesses in his interpretation are interrelated.

4. The Russian-Ukrainian framework

The Russian tradition about biogenic/abiogenic oil formation is very old, and both the possibilities were defended by their scientists. (Lomonosov, organic; Mendeleiev, abiogenic; and many others, in historical times, have adhered to the first or the second of parties).

More recently, Elansky (1966) and the Ukrainian Chekaliuk (1967) proposed a HP/HT mechanism of oil formation starting from mineral carbon (CO_2), hydrogen and methane. These chemical reactions are argued to happen in the mantle during serpentinization in presence of magnetite. Porfir'ev in his review of 1974 explained most arguments against the organic theory and he presented the history and reasons – within the limits of the scientific research of his time – of the inorganic origin idea. Today Kitchka (2004) is proponent of a model of oil and gas accumulation that occurs thanks to a slow vertical migration and coalescence of HCs fluid inclusions, through a fractured lithosphere and crust. In this volume, Rodkin & Shatakhtsyan (2012) propose an origin

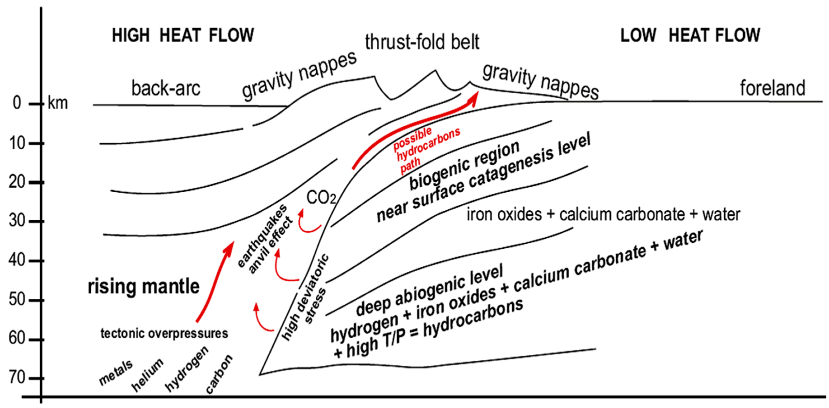

Fig. 3. A connection exists between the proposed model (Scalera, 2007b, 2008, 2010) and various kind of hydrocarbons generation. The convergence of cold and hot materials, of oxidizind and reducing environments, the presence of high nonlithostatic overpressures, and of ascending fluids and catalysts, constitute a favourable dynamical environment in which different types of metamorphism can be realized at shallower depths, ore deposits can form near the surface by concomitant self-organization processes and the synthesis of biogenic and abiogenic hydrocarbons can occur at depths not exceeding few tens of kilometres..

of hydrocarbons in zones where a non-equilibrium – tectonic, thermal, geochemical, etc. – is present.

Many others worked adopting the abiogenic conceptions, and Szatmari (1989) proposed that the industrially adopted Fischer-Tropsch chemical synthesis of artificial petroleum could also occur in the upper lithosphere. The needed high temperature and the too oxidizing state of upper mantle is a serious problem for the validity of the Szatmari' idea.

This criticism has been recognised by Kenney et al. (no date) – a collaborator of Gold in the Sijlian Ring drilling enterprise –, who have proposed what is considered the modern version of the abiogenic framework (Kenney et al., 2002). In their conceptions, the hydrocarbons are formed from abiogenic methane, but this is possible – because of constrains of the laws of thermodynamics – only to pressures greater than 30 kbar (depth > 100 km) and temperatures > 700°C. This great depth was formerly argued by Vernadsky (1933). If the environment is oxidizing – as it is in the upper part of the upper mantle, the impossibility to transform the organic remains of plants (carbohydrates) into hydrocarbons and oil follows from thermodynamics (Kenney et al., 2002). The Kenney's physical analysis is well grounded and experimentally confirmed (Scott et al., 2004) but somewhat static and formal. He does not take into consideration the real dynamical conditions of the lithosphere, whose physical state can be very different from his postulates.

5. Possible new armonic scenario of the hydrocarbons formation

As it has been shown in the preceding sections, all the conceptions of the proponents of abiogenic theories are in some aspect lacking of some important aspect of the geophysical reality. We must then ask to ourself if the difficulties to fully explain the origin of petroleum are caused by the deficiencies of the currently accepted global tectonics theory.

Oil and associated phenomena can be found preferentially along old fold belts and margins (Fig. 1 and 2), of which building models can be very different in different ideas of global tectonics. The fold belt building model proposed in preceding papers by Scalera (2007b, 2008, 2010) can be used to judge if the several difficulties encountered by the different biogenic/abiogenic conceptions can be solved (Fig. 3). In Fig. 3 the main characteristics of the model are shown in connection to the abiogenic/biogenic oil production problems.

Together with the higher temperatures available in the model of Scalera (2007b, 2008, 2010) at shallower depth, the tectonic overpressures (Mancktelow, 1995; Mancktelow & Gerya, 2008) can bear a relation with the synthesis of biogenic and abiogenic hydrocarbons.

Glasby et al. (2004) argued that most HCs fields occur in areas of higher than normal thermal gradient, and the above proposed model leads just to higher gradients that are produced by the isostatic uplift of very deep materials (from and above the transition zone). These higher gradients, together to the uplifted contents of mantle metals (catalysts) and hydrogen, can favour the occurrence of the conditions leading to the development of the Fischer-Tropsch reaction.

The underthrust carbonate slabs – formerly produced in the basin during the rift phases – can interact at proper high temperature with hydrogen and catalytic metals. The pressure range can be very wide both because the nonlithostatic overpressures (Mancktelow, 1995; Mancktelow & Gerya, 2008) at the boundary between uplifting material and adjacent stable or underthrust lithosphere, and occasionally because the inevitable occurrence of strong earthquakes (that can be considered a further supply of energy) in some periods of the thrust-fold belts building (Fig. 3 and 4). Laboratory experiments (Martinelli & Plescia, 2005) have recently ascertained that calcareous-marly rocks to which friction is applied produce a strong emission of carbon dioxide and methane of inorganic origin.

The compressional state of the gravity-driven nappes, together with the general rifting environment of the proposed model and the aperiodic activation of deep phase changes with extrusion of material below the fold belts, can be substantial facilitating factors in oil migration towards the surface following the slopes of the underthrust strata, and its final accumulation under impermeable layers. The negative experiment of the Sijlian Ring meteoritic crater drilling can be fully interpreted in this new framework as a proof of the insufficiency of the simple fracturing of the crust and lithosphere in favouring a surfacewards transferring of deep methane and other HCs. It needs a surfaceward uplift of deep materials, with an associated lithospheric fracturing provided by a rifting and/or thrust-fold belt building, to trigger the Fischer-Tropsch reaction.

The recurrent criticism (Glasby, 2006) of the lack of reducing condition in the upper part of the upper mantle to made possible the Fischer-Tropsch reaction, is then overcome in this model by means of the upwards isostatic transport of the transition zone reducing environment (Fig. 3). Also the criticism of Kenney that the suitable TP conditions to produce HCs can be found only at depth greater than 100 km is overcome by the transport of such conditions (Rodkin & Shatakhtsyan, 2012) toward the surface (Fig. 3).

The higher than normal $^3He/^4He$ rate that is observed in the HCs fields can properly be explained by the uplifting of undepleted mantle material, overcoming the difficulties explained by Peters (1999). Then, the results of Polyak (2005) based on isotopic and heat flow data (higher $^3He/^4He$ in areas of higher heat flow, and lower heat flow in areas of higher continental age. A surfaceward flow of silicate matter can explain the observation) – substituting his diapiric rising with an isostatic rising mechanism (as in my new proposed model) – can be considered an important support to this new proposed scheme.

The becoming very near, practically adjacent, of the reducing materials coming from the depths with the upper mantle oxidizing zone can be, in association with tectonic and seismic overpressures, the real forge zone – a sort of tectonic pile – of hydrocarbons, and of many kinds of metamorphism. The criticism of Kenney that the suitable TP conditions to produce HCs can be found only at depth greater than 100 km is then overcome by the transport of such conditions toward the surface (Fig. 3).

While in plate-tectonics the cold slab are carried to contact with the lithosphere of the continental side, oxidizing materials faced to oxidizing materials, in my framework a high-temperature reducing environment of undepleted mantle rises up and come in contact with the relatively cold oxidizing lithospheric environment. It is easy to check that in the interposed region of thermal gradient, and of the hydraulic gradient caused by non lithostatic overpressures (Mancktelow, 1995; Mancktelow & Gerya, 2008) – all at depths not greater than a few tens of km – a continuum of very different physicochemical conditions come in existence. A number of chemical reaction are then favoured in this sort of tectonic oxidizing-reducing pile, leading to a multiple origin of the hydrocarbons. However, yet any evaluation of the abiogenic/biogenic hydrocarbons rate is possible.

In addition, near to the surface – in the few first tens of kilometres – a considerable amount of fluids (Fyfe, 1978) and of organic biogenic material of various provenance is present in the underthrust sedimentary layers, which can participate with a passive (contaminant) or active manner (transmuting materials, kerogens) to the forming of hydrocarbons .

The many times claimed (Bastin, et al., 1926; Gold, 1992, 2001; among many others) and today ascertained (Head et al., 2003; among others) reality of the underground bacterial life, can be an additional factor in production of catalytic elements and/or in the biodegradation of HCs.

We should expect that an asymmetry in the amount and distribution of the HCs fields should result crossing an active margin. The cold side of these regions (e.g. the continental side of the Apennines, the Andes, etc.) should be more suitable for petroleum exploration, because the squeezing of fluids caused occasionally by the aperiodic overpressures towards the zones of decreasing horizontal hydraulic gradient. On the contrary, the horizontal flow toward the warm side should with great probability disintegrate the heavy HCs molecules – while they should conserve integrity going toward the cold region. It should be a matter of on-field experiments (drillings) the testing if the hydrocarbons are accumulated under the axial zone of the thrust-fold belts.

6. The Italian scenario of the hydrocarbons formation

A comparison of the Italian hydrocarbon fields with some major geophysical-geological features of the Italian region (see in Fig. 4 and 5 the hydrocarbons, CO_2 emissions, heat flow, volcanic, seismic, gravimetric, magnetic features) is useful to test the model. A simple comparison of the petroleum and gas fields (data from Pieri, 2001) with the maximum felt intensity (VIII, XI, X and XI MCS degrees) shows a initial good agreement between the model and the highest seismic energy release. The earthquakes seem to enclose an elongated area of tectonic working in which hydrocarbons can be produced in the depths and then expelled laterally toward the cold side of the region.

The "warm side" can be considered the region where the volcanic rocks and the highest-degree seismicity are located (Fig. 4 and 5). On this side HCs cannot migrate without be disintegrated. The oil and gas could benefit of the same mechanical action of the high stress – indicated by the earthquakes – in creating microfractures (before their coalescence in a bigger fault; see Crampin, 1999), through which these fluids can migrate towards oil fields or the surface. This migration can become a true expulsion with a possible occurrences of burst of flames during a seismic event. In Fig. 5b (from Caratori Tontini et al., 2004) the magnetic anomaly elongated from Ancona to Calabria is nearly coincident with the oil-gas fields pattern and it

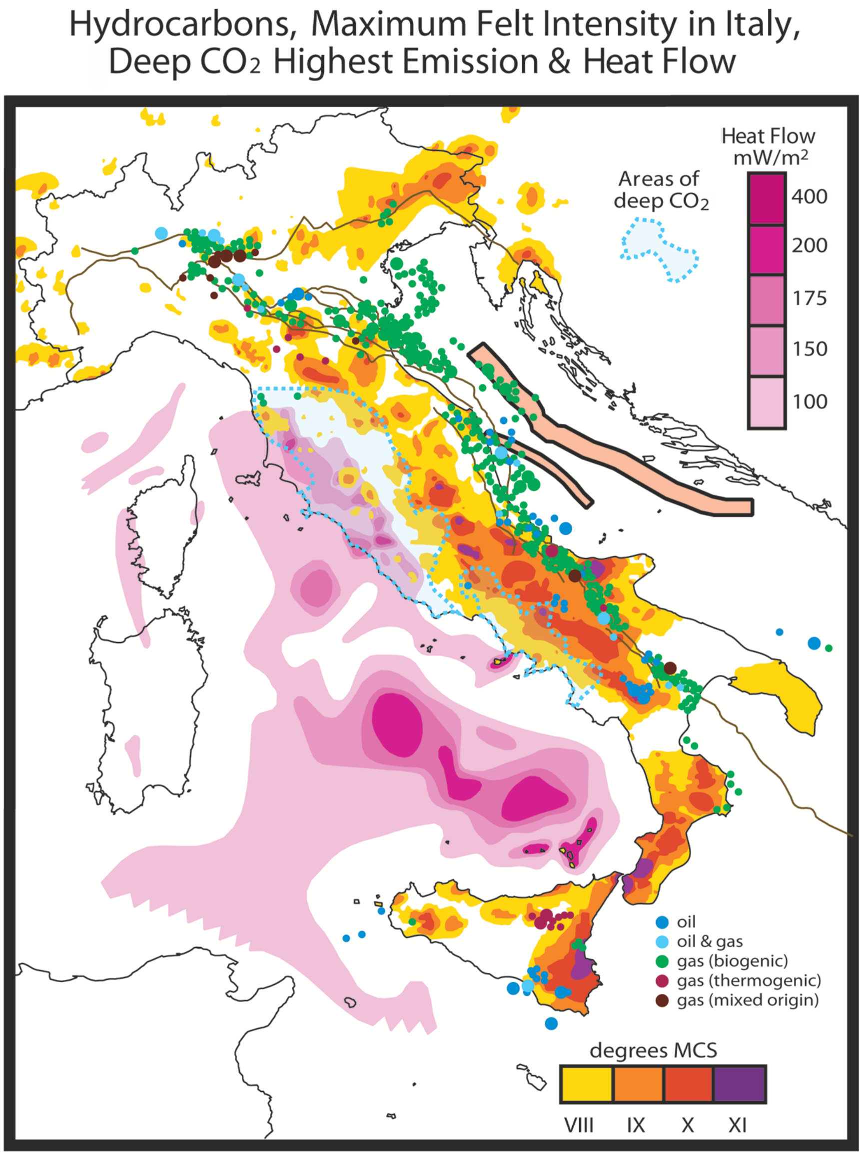

Fig. 4. The data of locations and productivity of hydrocarbon fields in Italy (Pieri, 2001). The maps of the MCS degrees from VIII to XI is extracted from the Maximum Felt Intensity in Italy that was elaborated by INGV (Boschi et al., 1995). The front of the orogen is also shown (from Bigi et al., 1991). The hydrocarbons are located beside the eastern side of the highest seismic energy releases. The further adding to this map of the zones of heat flow greater than 100 mW/m^2 (redrawn from the map by Della Vedova et al., 1991) shows that a similar warm/cold zonation exists like the one proposed in the model of Fig. 3. The highest CO_2 emissions (Chiodini et al., 2004) can be of mantle origin or can be produced by the margin of the underthrust carbonatic platform with the help of the earthquakes. Adjacent to the eastern side of the higher degree seismicity, and following the Adriatic plate margin (revealed by a long magnetic anomaly; see Fig. 5b), the hydrocarbons has been found in commercial quantities. They can come mostly or partially from the chemical reactions envisaged in this paper, and then pushed toward east by the hydraulic gradients and by the favorable disposition of microfractures and of impermeable sedimentary layers. The two flesh-coloured ribbons in the Adriatic sea represent main seismogenic faults (Basili et al., 2009) along whose new HC fields may be found.

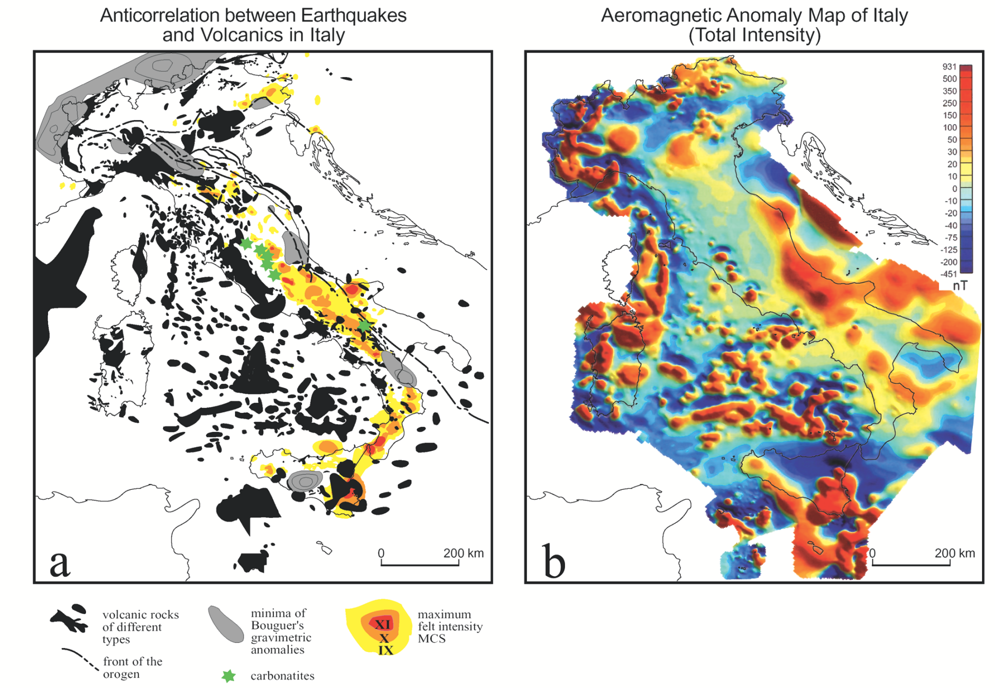

Fig. 5. In a) a comparison is shown between the higher values of the maximum felt intensity (IX, X, XI MCS degree) (Boschi et al., 1995) and all the volcanic facies (black areas) that are reported in "Structural Kinematic Map of Italy" (Bigi et al., 1991), in "Magnetized Intrasedimentary Bodies" (Cassano et al., 1986), and in Lavecchia & Stoppa (1996, carbonatites). The more energetic Apenninic seismicity is confined in the gaps of volcanics, and mainly immediately to west of the orogen front. Recently discovered carbonatites (green stars) help to better define the anticorrelation between volcanics and earthquakes. Another factor of inhibition of seismicity is the presence of minima of the Bouguer gravimetric anomaly, which are related to greater crustal thickness and/or to different characteristics of the crust. In b) a long alignment of large positive magnetic anomalies is recognizable in the total intensity map (Caratori Tontini et al., 2004) from Ancona to Calabria (similar results, although with higher frequencies, are shown in the map of Chiappini et al., 2000), which seems to delimitate the western boundary of the Adriatic lithosphere, where phenomena of extrusion of the magnetic basement are possible (Speranza & Chiappini, 2002).

constitutes the trace of the western edge of the Adriatic plate.

Albeit the pattern of the discovered oil fields does not reflect exactly the real oil-gas pattern – in the sense that a wider and different distribution will be possible in the case of numerous new findings – the actual situation seems in accord to the proposed model in which an important role should have the abiogenic hydrocarbons – in particular those produced by the tectonic working at the western of the Adriatic plate. Deeper investigations and analyses are needed in determining the the real rate (biogenic/abiogenic) of the Italian hydrocarbons.

7. Conclusions

The existence of huge amounts of hydrocarbons on the surface of little planetary bodies of the Solar System can have a more deep meaning. It is perhaps premature to draw a definite generalization from few facts still insufficient to be linked in a rigorous logical chain, but the generation of hydrocarbons on planets, the born of the underground and surface life, its thriving evolution, and some still unexplained properties of our Earth – such as its slow expansion (Scalera 1990, 1993, 2001, 2003; Scalera & Jacob, 2003; Lavecchia & Scalera 2006) –, appear so inextricably mutually linked to be deserving of guesswork.

Ever more, the Earth is not a mere scenarios of the happenings, but its role is important in driving them. The creation of a still not assessable amount of hydrocarbons by tectonic activity – driven from the global Earth's expansion – and the possibility that also the primordial life has been promoted by the same geodynamic behaviour of the active margins evoke wonderful conjectures.

If Croizat (1962) has for a long time defended the active role of tectonics in the process of creating vicariance and speciation (Humphries & Parenti, 1986), we can today envisage the same important involvement of tectonics in creating into the Earth depths the first organic self-reproducing molecules, preceding perhaps the surface life. And also we have to question ourselves how can be that similar tectonic mechanisms can have acted on so small celestial bodies, and what can be the energy able to sustain such processes on the planetary moons – tectonic processes are possibly in activity, for example, on Titan (Lorenz, 1996; Lorenz & Lunine, 1996). Can be that the problem of the origin of petroleum – to all the appearance only relevant for the prosperity of humankind – is in fact a clue or a key for solving more general problems – geological, cosmological and also eschatological? ... Or it is this only a beautiful dream?

References

Basili R., Kastelic V., Valensise G. and DISS Working Group (2009). DISS3 Tutorial Series: guidelines for compiling records of the Database of Individual Seismogenic Sources, version 3. Rapporti Tecnici INGV N.108, 16 pp.

Bastin E.S., Greer F.E., Merritt C.A., Moulton G. (1926). The presence of sulphate reducing bacteria in oil field waters. Science, 63 (1618), 21-24.

Bigi G., Castellarin A., Catalano R., Coli M., Cosentino D., Dal Piaz G.V., Lentini F., Parotto M., Patacca E., Praturlon A., Salvini F., Sartori R., Scandone P., Vai G.B. (1991). Synthetic Structural-Kinematic Map of Italy, CNR (Consiglio Nazionale delle Ricerche), Roma.

Boschi E., Favali P., Frugoni F., Scalera G., Smriglio G. (1995). Maximum Felt Intensity in Italy – Number of VIII Degrees Felt in Italy – Number of VII Degrees Felt in Italy, three maps 1:1.500.000. I.N.G. and Civil Protection Department, System Cart, Roma.

Brooks B.T. (1948). The origin of petroleum in the light of recent research. The Ohio Journal of Science, Vol. XLVIII (4), 129-145.

Caratori Tontini F., Stefanelli P., Giori I., Faggioni O., Carmisciano C. (2004). The revised aeromagnetic anomaly map of Italy. Annals of Geophysics, 47 (5), 1547-1555.

Carey S.W. (1975). The subduction myth. In: H. Messel and S.T. Butler (eds.) Our Earth. Shakespeare Head Press, Sydney, 146-167.

Cassano E., Fichera R., Arisi Rota F. (1986). Map of main intrasedimentary magnetic bodies (From the aeromagnetic survey AGIP of the "Magnetic basement structural model").

Chekalyuk E.B. (1967). Neft' verkhney mantii zemli (The oil of the upper mantle of the Earth). Naukova Dumka, Kiev, 256 pp.

Chiappini M., Meloni A., Boschi E., Faggioni O., Beverini N., Carmisciano C., Marson I. (2000). Shaded relief total field magnetic anomaly map of Italy and surrounding marine areas at sea level. Annali di Geofisica, 43 (5), 983-989.

Chiodini G., Cardellini C., Amato A., Boschi E., Caliro S., Frondini F., Ventura G. (2004). Carbon dioxide Earth degassing and seismogenesis in central and southern Italy. Geophysical Research Letters, 31, L07615, 1-4.

Chopin C. (2003). Ultrahigh-pressure metamorphism: tracing continental crust into the mantle. Earth and Planetary Science Letters, 212, 1-14.

Chudinov Y.V. (2001). Eduction concepts of the Earth's expansion theory. Main grounds, paleomagnetic evidences, metallogenic consequences.VSP, 166 pp.

Colombo U. (1972). L'origine del petrolio. Le Scienze (Italian edition of Scientific American), vol. VIII (43).

Crampin S. (1999). Calculable fluid-rock interaction. Journal of the Geological Society, London, 156, 501-514.

Crampin S. (2004). The new geophysics: implications for hydrocarbons recovery and possible contamination of time-lapse seismics. First Break, 22 (June 2004), 73-82.

Croizat L. (1962). Space, Time, Form – The Biological Synthesis. Privately Issued, 881 pp.

Cruikshank D.P., Apt J. (1984). Methane on Triton: Physical State and Distribution. Icarus, 58, 306-311.

Della Vedova B., Mongelli F., Pellis G., Squarci P., Taffi L., Zito G. (1991). Heat Flow Map of Italy (Scale 1/2500000). IIRG – International Institute for Geothermal Research, CNR, printed by S.E.L.C.A., Florence.

Dimitrov L.I. (2002). Mud volcanoes – the most important pathway for degassing deeply buried sediments. Earth-Science Reviews 59, 49-76.

Dott R.H., Reynolds, M.J. (compilers) (1969). Source Book of Petroleum Geology. Memoirs – American Association of Petroleum Geologists, 5, 471 pp.

Elansky L.N. (1966). Voda I neft' (Water and oil). In: Problema proishozhdeniya nefti (The problem of the origin of Oil), Nauvkova Dumka, Kiev, 103-121.

Etiope G., Klusman R.W. (2002). Geologic emissions of methane to the atmosphere. Chemosphere, 49, 777-789.

Fiebig J., Chiodini G. et al. (2004). Chemical and isotopic equilibrium between CO_2 and CH_4 in fumarolic gas discharges: Generation of CH_4 in arc magmatic-hydrothermal systems. Geochimica et Cosmochimica Acta, 68 (10), 2321-2334.

Fiebig J., Woodland A.B., Spangenberg J., Oschmann W. (2007). Natural evidence for rapid abiogenic hydrothermal generation of CH_4. Geochimica et Cosmochimica Acta, 71, 3028-3039.

Flores G., Pieri M. (1981). L'Italia Geologica – Storia degli ultimi 230 milioni di anni. Longanesi & C., Milano, 202 pp.

Fyfe W.S. (1978). Fluids in the Earth's Crust. Developments in geochemistry, Elsevier, 402 pp.

Fyfe W.S. (1996). The biosphere is going deep. Science, Washington, 273, 448.

Giardini A.A., Melton C.E. (1981). Experimentally-based arguments supporting large crustal accumulations of nonbiogenic petroleum. Jour. Petroleum Geol., 4 (2), 187-190.

Glasby G.P. (2006). Abiogenic origin of hydrocarbons: an historical overview. Resource Geology, 56 (1), 85-98.

Glasby G.P., Yamanaka T., Yamamoto J., Sato H., Notsu K. (2004). Kuroko and hydrocarbon deposits from northern Honshu, Japan: A possible common hydrothermal/magmatic origin? Resource Geol., 54, 413-425.

Gold T. (1987). Power from the Earth: Deep Earth Gas-Energy for the Future. Dent & Sons, London, 197 pp.

Gold T. (1991). Sweden's Siljan Ring well evaluated. Oil and Gas Jour., 89 (2), 76-78.

Gold T. (1992). The deep hot biosphere. Proceedings of the National Academy of Sciences, USA, 89, 6045-6049.

Gold T. (1993). The origin of methane in the crust of the Earth. U.S. Geol. Surv. Prof. Paper, 1570, 57-80.

Gold T. (2001). The Deep Hot Biosphere: The Myth of Fossil Fuels. 2nd edition, Springer-Verlag, Copernicus Book, 243 pp.

Gold T., Soter S. (1984). Fluid ascent through the solid lithosphere and its relation to earthquakes. Pure and Applied Geophysics, 122, 492-530.

Hand E. (2008). Plumes of methane identified on Mars. Nature, 455, 1018-1018.

Head I.M., Jones D.M., Larter S.R. (2003). Biological activity in the deep subsurface and the origin of heavy oil. Nature, 426, 344-352.

Hedberg H.D. (1969). Hypotheses for an inorganic origin. In: Dott R.H. and Reynolds M.J. (compilers) Source Book of Petroleum Geology. Memoirs – American Association of Petroleum Geologists, 5, 15-45.

Hilgenberg O.C. (1974). Geotektonik, neuartig gesehen (Geotectonics, seen in a new way). Geotektonische Forshungen, 45 (1-2), 194 pp.

Hobson G.D., Tiratsoo E.N. (1975). Introduction to petroleum geology. Scientifc Press Ltd., Beaconsfield, England, 300 pp.

Horita J., Berndt M.E. (1999). Abiogenic Methane Formation and Isotopic Fractionation Under Hydrothermal Conditions. Science, Vol. 285, 1055-1057.

Humphries C., Parenti L.R. (1986). Cladistic Biogeography (Chap. 4 on a comparison among tectonic theories – Expanding Earth among others). Clarendon Press, Oxford, 98 pp.

Katz B.J., Mancini E.A., Kitchka A.A. (2008). A review and technical summary of the AAPG Hedberg Research Conference on "Origin of petroleum – Biogenic and/or abiogenic and its significance in hydrocarbon exploration and production". The AAPG Bulletin, 92 (5), 549-556.

Kenney J.F., Kutcherov V.A., Bendeliani N.A., Alekseev V.A. (2002). The evolution of multicomponent systems at high pressures: VI. The thermodynamic stability of the hydrogen-carbon system: The genesis of hydrocarbons and the origin of petroleum. Proceedings of the National Academy of Science, USA, 99, 10976-10981.

Kenney J.F. et al. (no date). Dismissal of the claims of a biological connection for natural petroleum. http:// www.gasresources. net/ DisposalBioClaims.htm.

Kholodov V.N. (2002). Mud Volcanoes, Their Distribution Regularities and Genesis: Communication 1. Mud Volcanic Provinces and Morphology. Lithology and Mineral Resources, 37 (3), 197-209.

Kitchka A. (2004). Juvenile petroleum pathway: from fluid inclusions via tectonics and outgassing to its commercial fields. Nauka, Novi Pogliadi, 37-47.

Laherrere J. (2004). No free lunch, Part 1: A critique of Thomas Gold's claims for abiotic oil. Published on the website *FromTheWilderness.com.*

Lavecchia G., Stoppa F. (1996). The tectonic significance of Italian magmatism: an alternative view to the popular interpretation. Terra Nova, Vol. 8, 435-446.

Lorenz R.D. (1996). Pillow lava on Titan: expectations and constraints on cryovolcanic processes. Planetary and Space Science, 44, 1021-1028.

Lorenz R.D., Lunine J.I. (1996). Erosion on Titan: past and present. Icarus, 122, 79-91.

Lunine J.I., Lorenz R.D., Hartmann W.K. (1998). Some speculation on Titan's past, present and future. Planet. and Space Sci., 46, 1099-1107.

Lunine J.I., Yung Y.L., Lorenz R.D. (1999). On the Volatile Inventory of Titan from Isotopic Abundances in Nitrogen and Methane. Planet. and Space Sci., 47, 1291-1303.

Mancktelow N.S. (1995). Nonlithostatic pressure during sediment subduction and the development and exhumation of high pressure metamorphic rocks. Journal of Geophysical Research, 100 (B1), 571-582.

Mancktelow N.S., Gerya T.V. (2008). Non-lithostatic pressure during deformation. EGU General Assembly 2008, Vienna, Geophysical Research Abstracts, Vol. 10.

Martinelli G., Plescia P. (2005). Carbon dioxide and methane emissions from calcareous-marly rock under stress: experimental tests results. Annals of Geophysics, 48 (1), 167-173.

Mello M.R., Moldowan J.M. (2005). Petroleum: To be or not to be abiogenic. http://www. searchand-discovery. net/ documents / abstracts/ 2005 research_calgary/ abstracts / extended /mello/ mello. htm.

Milkov A.V. (2005). Global distribution of mud volcanoes and their significance as an indicator of active petroleum systems, a source of methane in the atmosphere and hydrosphere, and a geohazard. In: G. Martinelli and B. Panahi (eds.) Mud Volcanism, Geodynamics and Seismicity, NATO Science Series Volume, Springer, 29-34.

Mumma M.J., Villanueva G.L., Novak R.E., Hewagama T., Bonev B.P., DiSanti M.A., Mandell A.M., Smith M.D. (2009). Strong Release of Methane on Mars in Northern Summer 2003. Science - Sciencexpress, 15 January 2009, 1-6.

Ollier C.D. and Pain C.F. (2000). The Origin of Mountains. Routledge, London, 345 pp.

Pedersen K. (2000). Exploration of deep intraterrestrial microbial life: current perspectives. FEMS Microbiology Letters, 185, 9-16.

Peters K.E. (reviewer) (1999).The deep hot biosphere by Thomas Gold. Organic Geochemistry, 30, 473-475.

Pfeiffer J. (2005). No free lunch, Part 2: If abiotic oil exists, where is it?. Published on the website *FromTheWilderness.com*.

Pieri M. (2001). Italian petroleum geology. In: G.B. Vai, I.P. Martini (eds.) Anatomy of an Orogen – The Apennines and Adjacent Mediterranean Basins. Kluver Academic Publishers, London, 533-549.

Pieri M., Mattavelli L. (1986). Geologic framework of Italian petroleum resources. The AAPG Bulletin, 70 (2), 103-130.

Polyak B.G. (2005). Heat and mass transfer from the mantle: heat flow and He-isotope constraints. Annals of Geophysics, 48 (1), 9-17.

Polyak B.G., Smirnov Ya.B. (1966). Heat flow in the continents (in Russian). Russ. Acad. Sci. Rep., 168 (1), 170-172.

Polichtchouk Y.M., Yashchenko I.G. (2006). Possible correlation between crude oil chemical composition and reservoir age. Journal of Petroleum Geology, 29 (2), 189-194.

Porfir'ev V.B. (1974). Inorganic origin of petroleum. AAPG Bulletin, 58 (1), 3-33.

Pratsch J.-C. (1978). Future hydrocarbon exploration on continental margins and plate tectonics. Journal of Petroleum Geology, 1 (2), 95-105.

Rodkin M.V., Shatakhtsyan A.R. (2012). Main Statistical Features of Major Ore and Oil Deposits – Is the Deposits' Formation Connected With Transformation of Matter Between Different Chemical Reservoirs of the Earth's Interior?. This volume.

Sachan H.K., Mukherjee B.K., Bodnar R.J. (2007). Preservation of methane generated during serpentinization of upper mantle rocks: Evidence from fluid inclusions in the Nidar ophiolite, Indus Suture Zone, Ladakh (India). Earth and Planetary Science Letters, 257, 47-59.

Scalera G. (1997). The relation among seismic activity, volcanic rock emplacement and Bouguer anomalies in Italy. Natural Hazards, 15, 165-181.

Scalera G. (2003). The expanding Earth: a sound idea for the new millennium. In: G. Scalera and K.-H. Jacob (eds.) Why Expanding Earth? – A book in Honour of Ott Christoph Hilgenberg. INGV Publication, Rome, 181-232.

Scalera G. (2005a). A new interpretation of the Mediterranean arcs: Mantle wedge intrusion instead of subduction. Boll. Soc. Geol. Italiana, Volume Speciale no. 5, 129-147.

Scalera G. (2005b). The geodynamic meaning of the great Sumatran earthquake: inferences from short time windows. New Concepts in Global Tectonics Newsletter, n. 35, 8-23.

Scalera G. (2006a). The Mediterranean as a slowly nascent ocean. In: Lavecchia G. and G. Scalera (eds.) Frontiers in Earth Sciences: New Ideas and Interpretations. Annals of Geophysics, Supplement to v. 49, 451-482.

Scalera G. (2006c). The geodynamic meaning of the deep earthquakes: first clues for a global perspective for fold belts? New Concepts in Global Tectonics Newsletter, n. 41, 45-54.

Scalera G. (2007a). Geodynamics of the Wadati-Benioff zone earthquakes: The 2004 Sumatra earthquake and other great earthquakes. Geofísica Internacional, 46 (1), 19-50.

Scalera G. (2007b). A new model of orogenic evolution. Rendiconti della Società Geologica Italiana, Nuova Serie, 5, 214-218.

Scalera G. (2008). Great and old earthquakes against great and old paradigms – paradoxes, historical roots, alternative answers. Advances in Geosciences, 14, 41-57.

Scalera G. (2010). Biogenic and abiogenic hydrocarbons in Italy. Rendiconti online della Società Geologica Italiana, 11, 451-452.

Scalera G. (2010). Earthquakes, phese changes, fold belts: from Apennines to a global perspective, GeoActa, 3, 25-43.

Scalera G., Jacob K.-H. (eds.) (2003). Why Expanding Earth? – A book in Honour of Ott Christoph Hilgenberg. Proceedings of the 3rd Lautenthaler Montanistisches Colloquium, Mining Industry Museum, Lautenthal (Germany) May 26, 2001 (INGV Publication, Rome), 465 pp.

Schulze-Makuch D., Irwin L.N. (2004). Life in the Universe – Espectations and constraints. Springer-Verlag, Berlin, 172 pp.

Scott H.P. et al. (2004). Generation of methane in the Earth's mantle: In situ high pressure-temperature measurements of carbonate reduction. Proceedings of the National Academy of Sciences (USA), 101 (39), 14023-14026.

Serri G., Innocenti F., Manetti P. (2001). Magmatism from Mesozoic to Present: petrogenesis, time-space distribution and geodynamic implications. In: G.B. Vai and I.P. Martini (eds.) Anatomy of an Orogen – The Apennines and Adjacent Mediterranean Basins, Kluver Academic Publishers, London, 77-104.

Sherwood Lollar B. et al. (2008). Isotopic signatures of CH_4 and higher hydrocarbon gases from Precambrian Shield sites: A model for abiogenic polymerization of hydrocarbons. Geochimica et Cosmochimica Acta, 72, 4778-4795.

Sommaruga C., Zan L. (compilers) (1995). Geothermal Resources, in relation to plate tectonics – World Exploration and Development. A map, Third Edition, AQUATER S.p.A., S. Donato Milanese, Italy.

Spencer J.R., Buie M.W., Bjoraker G.L. (1990). Solid methane on Triton and Pluto: 3- to 4-m spectrophotometry. Icarus, 88 (2), 491-496.

Speranza F., Chiappini M. (2002). Thick-skinned tectonics in the external Apennines, Italy: New evidence from magnetic anomaly analysis. Journal of Geophysical Research, 107 (B11), 2290, doi:10.1029/2000JB000027, 8, 1-19.

Stoppa F., Woolley A.R. (1997). The Italian carbonatites: field occurrence, petrology and regional significance. Mineralogy and Petrology, Vol. 59, 43-67.

Szatmari P. (1989). Petroleum formation by Fischer-Tropsch synthesis in Plate Tectonics. The American Association of Petroleum Geologists Bulletin, 73 (8), 989-998.

Szatmari P., Da Fonseca T.C.O., Miekeley N.F. (2005). Trace element evidence for major contribution to commercial oils by serpentinizing mantle Peridotites. http://www.searchanddiscovery.net/ documents/ abstracts/ 2005research_calgary/ abstracts/ short/ szatmari.htm

Whitman W.B., Coleman D.C., Wiebe W.J. (1998). Prokaryotes: the unseen majority. Proceedings of the National Academy of Sciences (USA), 95, 6578-6583.

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