History of Ischia Harbour (Southern Italy)

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1 Introduction

On 17 September 1854, under the initiative of the Bourbon Ferdinand II (1830–1859), King of the Two Sicilies, the opening of the new harbour of Ischia was celebrated. It has since become a major maritime port and marina in the Bay of Naples (Fig. 1).

The port constituted the fundamental marine transporation element connecting the island and the mainland, providing easier access to the island and promoting the progressive growth of the local economy. At the time, Ischia showed great diversity between one zone and another, and much of the island was almost inaccessible and sparsely inhabited. Noted for its active volcanism from the early fourteenth century and persistent seismicity until 1883, "before 1853 this island was almost impracticable, … to the detriment of many natural advantages that it has over others, it had a wild appearance, to say the least" (Annali Civili del Regno delle Due Sicilie—Annals of the Kingdom of the Two Sicilies 1855).

However, due to its morphological characteristics and nature of its settlements, the northern side held out more attractions: the coastline was low and from here it was easier to reach Ischia Castello, the administrative centre of the island. In particular, occupying the site of the present-day harbour of Ischia was a lake close to the coastline, surrounded by low rises generated by recent volcanic activity. On the most southerly hill rose the house of chief Court Physician Francesco Buonocore that had been built during 1735 on family-owned land at the back of the central section of the lake nearly opposite today's harbour entrance. It was a

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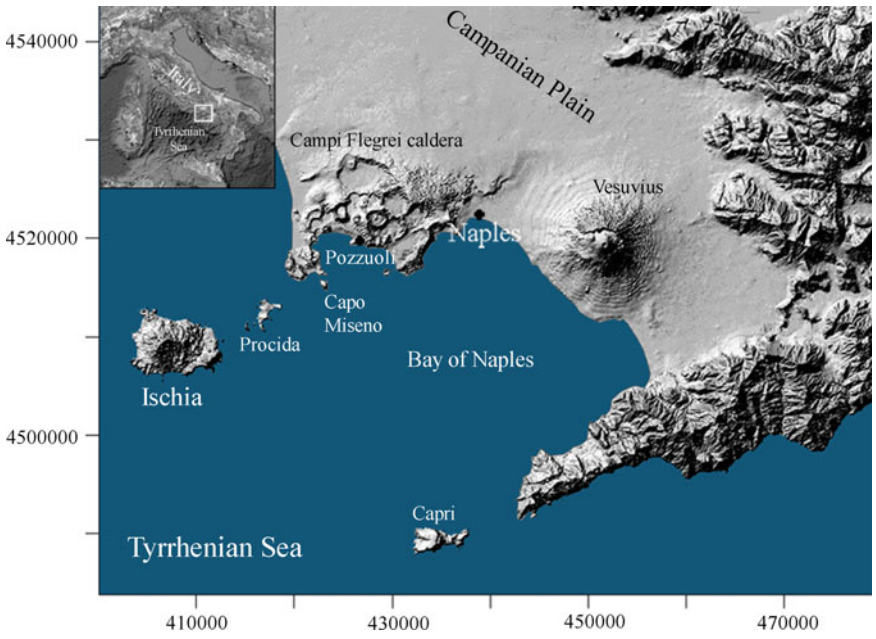

Fig. 1 The Bay of Naples and the island of Ischia

country villa which captured the spa waters bubbling up from underground and had thus become a house of health and well-being for nobles and dignitaries attached to the court of Naples who needed treatment.

The site had already been chosen by an earlier Bourbon king, Ferdinand IV, as a "royal delight" (1784), insofar as it was suitable for sating his passion for nature and for fishing in the lake. Later, in 1854, it was to come within the town-planning programmes of the northern side, carried forward by Ferdinand II, which led to the establishment and rapid development of Villa de'Bagni, the original name of the first settlement of Ischia Porto (Quaranta 1855). (The numbering of Ferdinand's royal titles is somewhat confusing. He was, in fact, Ferdinand IV of Naples and became, at a later stage in his reign, Ferdinand I of the Two Sicilies.)

An ancient volcanic formation dating to the fourth century BC, the lake was perfectly suited to being converted into a harbour. Known as the *Lago del Bagno* or *de' Bagni* due to the presence of hot springs on its perimeter, it was almost circular and deep enough to provide keel clearance for small fishing vessels. Moreover, it was separated from the sea by a small isthmus: a narrow sandy dune on which marine vegetation was deposited during rough seas. Since time immemorial, the lake had been used for fish-farming, constituting one of the few sources of revenue for the local administration.

The lacustrine basin, just like the rest of the island, was the product of volcanic activity which generated an extraordinarily complex landscape in continuous evolution (Figs. 2a, b, 3). This is due to the island's geological history which has

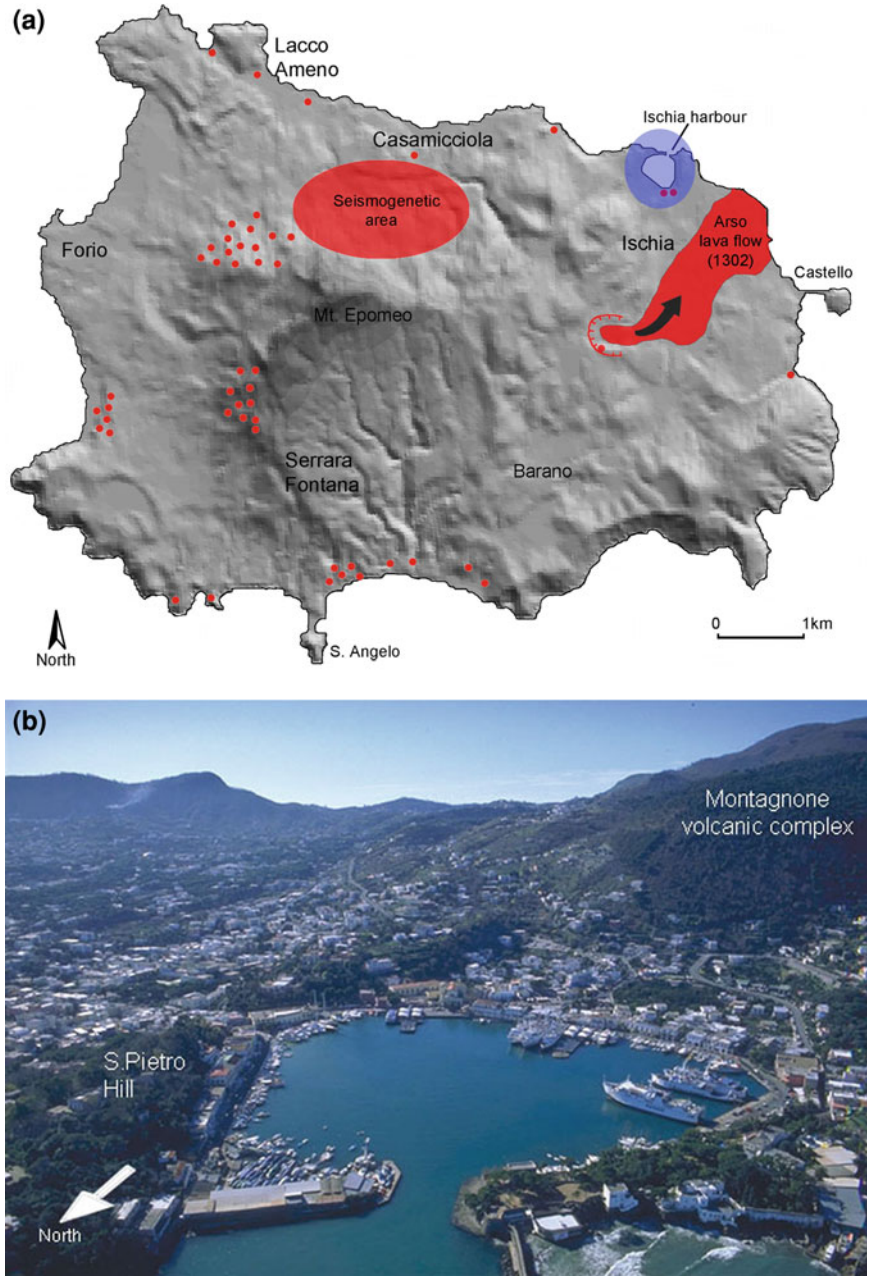

Fig. 2 The island of Ischia and main features related to its recent dynamic; *dots* represent the main hot springs and fumaroles fields (**a**) (modified after Luongo et al. 2006). The *circle* highlights the Ischia Harbour zone (**b**)

Fig. 3 The Ischia island as appears from the ferryboat which comes from Naples. On the right side (north), the top of Mt. Epomeo. It is also marked the Ischia harbour zone and the Castello lava dome (photo S. Carlino, 2008)

been distinguished by alternating explosive and effusive eruptions which have created a very variegated area, owing to the presence of many eruptive centres being partly destroyed or covered by subsequent volcanic activity, of deep valleys produced by erosion of pyroclastic top layers, of marine terraces and hills with sub-vertical walls, which testify to volcanic and tectonic processes on the island, especially active in the last 10,000 years, and with intense seismic activity recorded historically in the past 800 years. The most recent major volcanic eruption occurred in 1302, emitting a lava flow that affected the eastern side of Ischia, partly invading the area east of the harbour (Fig. 2a) (Vezzoli 1988; Civetta et al. 1991; Cubellis et al. 2004; Carlino et al. 2006; Luongo et al. 2006).

The main historical sources for information on the opening of the harbour, an operation which was to change the lives of the islanders, the morphology of the area, and the roles and hierarchy of the island's settlements are the Annali Civili del Regno delle Due Sicilie (1855), which supply technical and descriptive elements mixed with notes of praise and celebration for the king. The technicians entrusted with the task of cutting the isthmus to join the lake with the sea had, in the nearby Campi Flegrei, known historically as the Phlegraean Fields, the example of the work of Lucius Cocceius Auctus in 37 BC, who cut the isthmuses separating the Lucrine Lake from the sea and from Lake Avernus to build *Portus Iulius* (Fig. 4a, b) for the Roman fleet.

A further important source is the constant flow of correspondence between Camillo Quaranta, appointed commissioner for harbour works, and the king and the various ministers of the Bourbon Royal House, varyingly involved in operations (Naples State Archive, Ministry of Public Works). Recent years have seen some critical reviews of this source (Delizia 1987, Delizia and Delizia 2006; Rispoli 2007). Archaeological reconstruction of the area (Buchner 1946; Rittmann

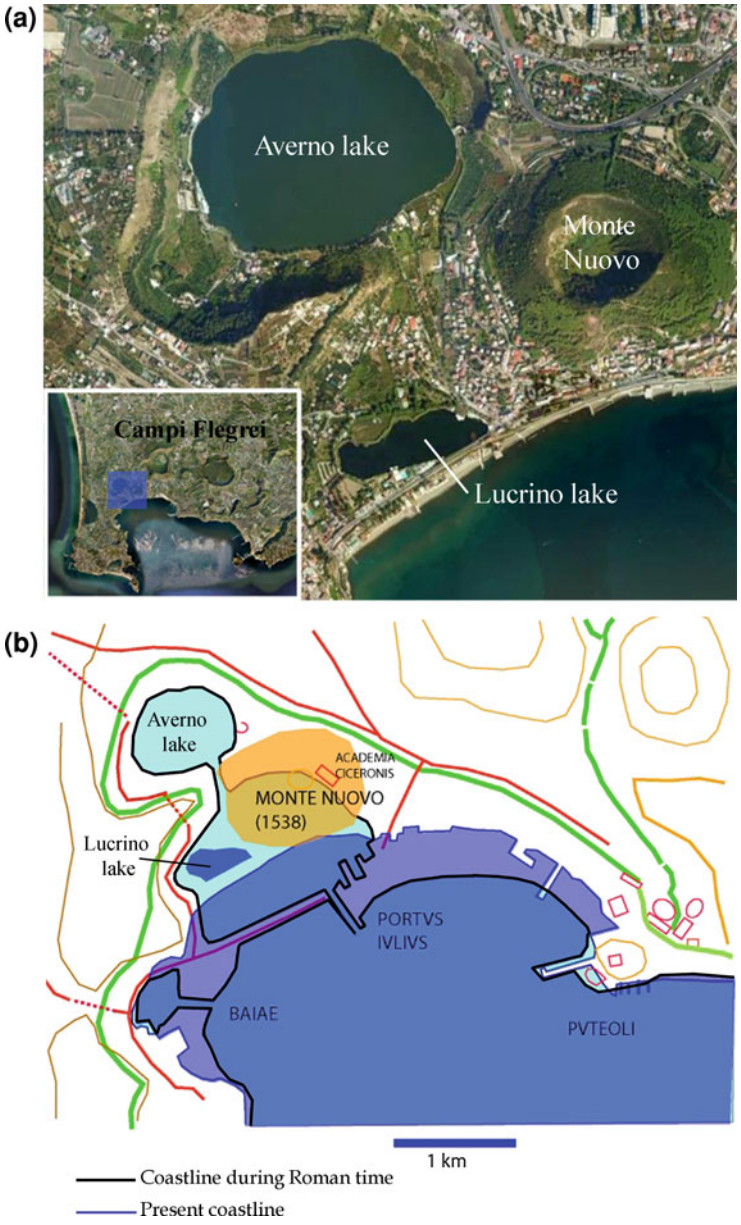

Fig. 4 Campi Flegrei Caldera - Avemus and Lucrine lakes and Mt. Nuovo tuff cone (1538) (**a**). During Roman times the isthmus which separated the two lakes was removed in order to obtain a channel for the passageway of the Roman fleet (Portus Iilius). The products of Mt. Nuovo eruption covered a large part of Lucrine lake (**b**). The submerged archaeological ruins indicate that the ground level of the Roman times is lower than the present-day one.this result is due to subsidence and resurgence processes occurred in the last 2000 years (Castagnoli 1977; Morhange et al. 2006; Pappalardo 2006)

and Buchner 1948), together with volcanological studies, has sketched out a reconstruction of the relations between prehistoric settlements and eruptions, as well as variations in the coastline in the last 2000 years.

No less important for our analysis is the maps (Alisio and Valerio 1983) and iconographic representations (Caputo 2000) produced either side of the great conversion of the lake into a harbour. Towards the mid-nineteenth century, the island's geology and natural history were the subject of extensive scientific inquiry, as ably illustrated in the geological maps of Fonseca (1847) and Fuchs (1873).

The set of available data, studies and reports are analysed herein to reconstruct the circumstances that led to the opening of Ischia Harbour, the macro-execution phases and the resulting change in the island's morphology. Our historical analysis is followed by the description of the geology of the harbour, some considerations on the current state of the island and on issues relating to the increase in volcanic and seismic risk resulting from urban expansion and the increase in tourism since the early twentieth century.

2 The Historical, Social and Cultural Context

The opening of Ischia Harbour occurred in a period that saw the considerable reforming impetus of public works throughout the Bourbon kingdom in southern Italy, especially in the region of Campania. This climate of reform started under the Spanish viceroy in 1610 when the first major intervention was launched in the region, the construction of a channel across the Campanian Plain north of Naples, the so-called Regi Lagni (Fiengo 1988), whose aim was to avoid the recurrent floods tormenting the local people and preventing urban growth since the pre-Roman period.

As often happens in the history of great monarchies, in southern Italy both during the Bourbon and French dominations (1737–1860), the sovereigns used to prove their greatness and benevolence by carrying out public works on a "grand scale", at the same time providing essential contributions for regional change and improvement. Modern macro-engineering endeavours are equivalent to "grand scale" in olden times. The city of Naples and its surrounding areas were protagonists of such modernizing change. This active involvement would ultimately lead to the founding of the Naples school of engineering, thanks to a decree of 18th November 1808, upon the initiative of Joachim Murat, which established the *Engineers Corps for Bridges and Roads*. Thus, arose the imposing figure of the all-directing State engineer, whose career was founded on a mostly meritocratic basis, in the interests of more rational land use.

With the arrival of the Bourbon Ferdinand II in 1830, the city of Naples and its surrounding areas experienced a period of considerable economic development, which gave it a modern, advanced image. In this period the first gas-lights were installed in the streets of Naples, roads and communication networks in general

were improved and built ex novo, and in 1839 the first railway line established in Italy was built, connecting the city of Naples with the town of Portici situated on the slopes of Vesuvius. Also the island of Ischia was included in this vast programme of public works, some of which never progressed beyond the project planning phase. However, it cannot be denied that the Bourbons did much for the island (D'Ascia 1867): new highway networks were opened up, hugely improving road communications over very rugged terrain; a new ~4.8 km-long section of the freshwater aqueduct was built, submarine telegraphic links were established between Ischia and the mainland; the Portosalvo church was built and the harbour was created, opening up new horizons for developing the island's economy. The presence of a safe port, whose natural morphology made it sheltered from the westerly storms that create havoc in the Bay of Naples (Fig. 5), continues to be an essential function. Since Bourbon times, it has made the island easily accessible from the ports in Naples, Pozzuoli and Capo Miseno.

It was precisely in the early nineteenth century that systematic navigation in the Tyrrhenian sea began with the aid of large steamships, designed in the late eighteenth century in the USA, then in the UK and Italy. The invention of the steamship was so well received in the Kingdom of the Two Sicilies that King Ferdinand II, on the proposal of the Minister of Finance, decided to start up a shipbuilding industry. The Kingdom of the Two Sicilies became the third largest steamship producer in the world and the first in the Mediterranean.

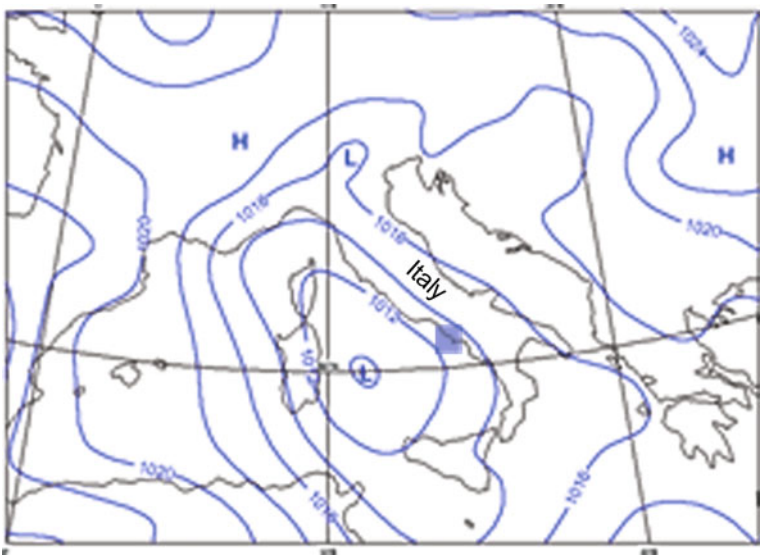

Fig. 5 Typical low pressure over the Tyrrhenian Sea which produces NW and SW winds and waves in the western and eastern sector respectively. The Bay of Naples is highlighted with a *square* (wetteronline.de)

However, the cultural climate of that time and region was not characterised only by the spirit of innovation and industrial development: the late eighteenth century saw the start of the first scientific studies which were to lead to the birth of modern geology and for which the island of Ischia would play an important role in interpreting geological phenomena. The publication of *Principles of Geology* (1830) by Charles Lyell (1797–1875) who followed the Scottish James Hutton's (1726–1797), *Theory of the Earth with Proofs and Illustrations* (1795) gave a new impetus to studying the Earth's dynamics (Fischer and Garrison 2009). Lyell was in Naples in October 1828, attracted by the minute description of the rocks of the island of Ischia which the geologist Gian Battista Brocchi had made during his stay in Naples between 1811 and 1812. For Lyell the volcanic areas and recently-formed soils assumed considerable importance for his theory of gradualism, because he felt that in the Earth's history the causes which today slowly change the Earth's surface had always acted. The proof of this came from recent soils, where major changes were still under way. Lyell headed for Ischia, where he found fossil shells of marine origin on Mt. Epomeo as high as 600 m, with which he was able to demonstrate, with the aid of the Neapolitan naturalist Oronzo Gabriele Costa (1787–1867) who identified the fossils, that the island had recently undergone substantial tectonic uplift.

The drive towards research in actual geology also came from the need to identify and harness natural resources, especially energy resources needed to develop the industries that were arising in the technologically more advanced European countries. The positivist movement was to dominate much of European scientific and literary culture in the nineteenth century. Empirical facts were considered as underlying all real knowledge. In this social climate the Industrial Revolution started: in the UK between 1780 and 1800 there were major changes in the means of production, new sources of raw materials began to be exploited, new markets were opened up, the human population increased rapidly, and deep-rooted changes were occurring in the structure of settled society.

In southern Italy, under Bourbon domination there was a period, albeit short-lived, when great advances were made in science and especially in volcanology, concluded immediately after the Conference of Italian Scientists, held in Naples, in 1845 (Luongo 1989). For scientists, the theatre for volcanological developments consisted of the active volcanoes of Vesuvius, Campi Flegrei and Ischia, which represented a type of "golden triangle", with the metropolis of Naples in the middle. The historical and social context in which Ischia harbour was opened was thus a period of considerable cultural and scientific ferment, infused by a spirit of technical and industrial innovation. However, the reasons that led to the harbour at Ischia being opened were primarily linked to personal choices made by King Ferdinand II, to his fondness for the site as a holiday residence for the royal family. That said, the choice was also conditioned by the far-sighted political vision which was the hallmark of the king's main undertakings: this was still virgin territory, susceptible to developmental changes that would eventually leave the unmistakable mark of the Bourbon monarchy.

2.1 First Settlements and Development of the Island

Once known by the name of *Pithecusa,* the island of Ischia was the site of the earliest known Greek settlement in Italy. It was founded by Euboean Greeks from Eretria and Chalcis *in* ca. 770 BC who established a flourishing trading post in the present-day bay of San Montano, followed in the fourth century BC by a small settlement on the north-eastern coast, now the site of the port of Ischia (Buchner 1971; Monti 1968, 1980). At a later date, a violent cataclysm is reported, which not only drove away the first Greek peoples, but also changed the configuration of the landscape: it brought about the depression of a coastal stretch with the formation of the lake and the small volcanic edifices of Montagnone and Rotaro. We hear of this event from the period's great polymath, Pliny the Elder, who died at Stabiae following the eruption of Vesuvius in 79 AD. In his *Naturalis Historia* (23–79 AD), he writes that on the island of Ischia, then called Aenaria, the earth swallowed up a now-forgotten unnamed town—*oppidum haustum profondo*—and that after this catastrophe a lake was formed—*alioque motu terrae stagnum emersisse*. Indeed, below the products of the eruption that led to the formation of the *Lago del Bagno* the remains of sixth and fifth century BC pottery were found, besides roof tiles from a Greek temple of the same era, now conserved in the island's museum (Buchner and Gialanella 1994; Buchner 2004).

Volcanic activity was such that the cultures that followed did not leave very significant traces of their presence on the island. The "rediscovery" of Ischia only occurred from the mid sixteenth century onward, when Giulio Iasolino (1538–1622), a medical doctor from Calabria, professor of anatomy at Naples University, started a systematic, painstaking study of all the hot springs on the island, which he introduced into curative practice. The long task of analysing and recognising the hot springs culminated in 1588 with the publication of *De' rimedi naturali che sono nell'isola di Pithecusa, hoggi detta Ischia* (On the natural remedies on the island of Pithecusa, today called Ischia) (Iasolino 1588), a work of great importance and editorial success, which was to boost Ischia's fame, thanks in part to the useful map of sites included, engraved by the mapmaker from Viterbo, Mario Cartaro, which was later used in the most important European atlases.

Interest in Ischia may also have grown due to the eruption of the nearby Campi Flegrei in 1538, which made the more popular thermal baths of Pozzuoli and Baia impracticable (Buchner 1958). From this time on, visitors to Ischia would be lured and connected to the development of the bathing and spa treatment industry which the pioneering construction of the Pio Monte della Misericordia establishment at Casamicciola (1601–1603), on the Gurgitello springs, contributed to inaugurate, develop and spread.

In the mid nineteenth century, there were already 12 spas/bathing establishments on the island where "the infirm flock from every part of Europe to try out the beneficial effects of these gifts that nature appears to have bestowed generously on this island" (Annali Civili del Regno delle Due Sicilie 1855). The island's ancient rural vocation, chiefly linked to wine production, would gradually give

way to an economy based on spa and recreational tourism. As a result, there was an influx of new monetary capital that increased hotel capacity. The island's economy would progressively grow, but the inhabitants would continually have to come to terms with the forces of nature: in 1881 and 1883 the island was shaken by two large earthquakes which devastated island's northern sector, with the epicentres between the Casamicciola and Lacco Ameno municipalities. The earthquake of 28 July 1883 was especially destructive: it caused almost all the buildings in Casamicciola to collapse, heavy damage in almost the whole island and led to a death toll of 2,333 persons, many of whom were tourists. In the worst-hit municipalities there ensued a period of economic recession and a population decrease that would only begin to recover in the early twentieth century (Fig. 6) (Cubellis and Luongo 1998; Cubellis et al. 2004; Luongo et al. 2006; Carlino et al. 2009).

After the Second World War, starting ca. 1950, the tourist flow would increase, with a consequent chaotic, undisciplined boom in construction on the land, due to the lack of authoritative land-use planning regulation. This led to an aggravation, besides other things and events, of the volcanic and seismic risk to people and infrastructure. Today the island has six lawful municipalities (Ischia: 18,253 inhabitants; Casamicciola: 7,374; Lacco Ameno: 4,273; Forio: 14,554; Serrara Fontana: 3,060; Barano: 8,591, ISTAT data) making up a total population of >56,000 persons. The island's three main municipalities have boat and yacht marinas. Only that of Ischia is a natural ship harbour.

Since the opening of Ischia Harbour in 1854, the island has undergone radical economic, social and environmental changes. New shipping routes have permitted a rapid increase in daily commuter flows to and from the island. However, nowadays, more than four million tourist visitations impact the island every year, most people visit during May to September. Natural human population increase, tourism and urban region expansions have brought about an exponential increase in risk

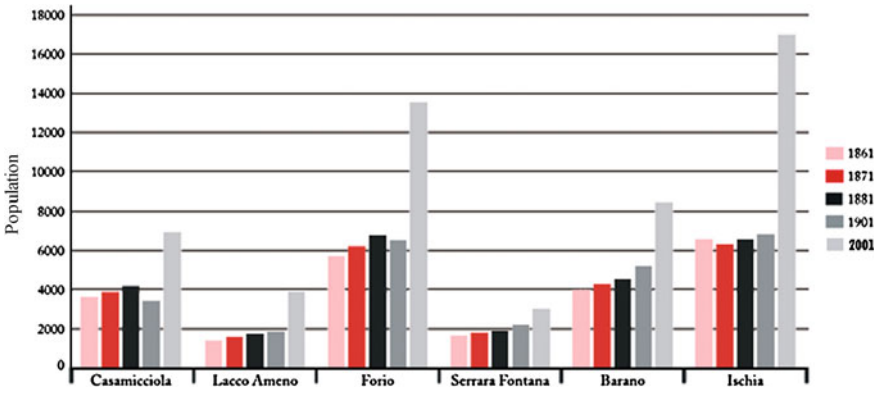

Fig. 6 Population growth on the island from 1861 to present (ISTAT). After the 1883 earthquake there was a slight population decrease in the northern and western sectors (Casamicciola and Forio). A rapid increase has occurred in recent times (from Luongo et al. 2006)

correlated with seismic and volcanic activity. Besides, the island has been stricken in recent times (1910, 2006, 2009) by floods that have caused serious damage and dozens of victims, especially in the northern sector (Cubellis et al. 2008, 2009; Luongo 2009; Carlino et al. 2010). Attention is thus also laid on all those macro-management problems linked to the region's vulnerability and the consequent increase in risk (Alberico et al. 2008) which has now reached levels that are no longer publicly acceptable, compromising the island's basic vocation as a "place of well-being" in which the adventurous, tired, sickly and healthy alike can enjoy the unique and picturesque beauty of "civilized" volcanic landscapes. There have been a few seawater pollution episodes caused by industrial activity and shipping in the bay region nearby Ischia Harbour.

3 The Lake of Bagno Before the Harbour's Construction: Descriptions and Representations

"Only a sandbank, about 50 feet wide, separates it from the sea: it is a small version of a Dead Sea, with the difference that the lacustrine basin three-quarters of a mile in circumference is the bed of an ancient volcanic crater, formed by the small promontory of lava of S. Pietro a Pantanello to the east by the volcanic hills of Sant' Alessandro to the west and north. This lake has been given the inappropriate name of Pantanello which means little marshy pond; it communicates with the sea via a channel dug at the end of the sandbank. Hence the water is continuously changed in the basin, which has a sandy bed and resembles a pond full of exquisite fish, mussels and other crustaceans. At the centre of the lake rises a lava rock on which there is a small hut for fishing tackle which is let, reaping revenue for the town of Ischia. On the western shore of the lake there is an estate endowed with almost everything that constitutes, in this place, a good rural economy. The residence is small but clean. Suited to the needs of its owner it is situated at the centre of the vegetable garden that extends across the lower part of the estate, almost on the water's edge" (Haller 1822). Thus Conrad Haller, a French traveller to the Bay of Naples, described what would be the future harbour of Ischia, a circular lake, the so-called Lago del Bagno, formed within an ancient volcanic crater whose circumference measured 1.2 km, separated from the sea by a sandbank 15–20 m wide and about 250 metres long. Albeit relatively small, about 115,000 m^2, the stretch of brackish water was more similar to a lake than a marshy pond (pantano), since it communicated with the sea thanks to a small man-made channel, called Bocca Vecchia (old mouth), which allowed the continuous change of water and, closed off by a lock, favoured the proliferation of fish and crustaceans. The small lake was, thus, an ideal place for fishing, for the farming of molluscs and crustaceans, but also for the hunting of coot and other waterfowl.

With the iconographic and cartographic representations of the *Lago del Bagno* before its conversion into a harbour, the morphology of the site—and the

sentiment it inspired—can be fairly faithfully reconstructed. Such was the enchantment of the site that the Bourbon kings, Ferdinand IV, and later Francis I and Ferdinand II, succumbed to its appeal, so as to make it become a work of total transformation which led to the creation of the royal residence on the island. It was precisely with this in mind that Ferdinand IV commissioned the court artist, Philip Hackert, in 1792, to paint a view of the area. Exhibited in the Palace of Caserta in the Room of Ferdinand IV, the painting depicts the whole stretch of the lake with the Aragonese Castle in the background and on the eastern shore the Buonocore lodge, now residence of the Bourbons. The lodge became the property of the royal household following a donation made by the descendants of Francesco Buonocore, even though it would appear to have been an appropriation rather than a spontaneous donation. Besides, Hackert's painting depicts in the foreground fishermen intent on casting their nets from small boats, a fairly profitable activity for the local community (Fig. 7). In the central sector of the lake the small lava rock described by Haller can be seen, with the storehouse for fishing tackle on top. This block of lava represents the remainder of a magmatic body which had fuelled the eruption, later solidified within the volcanic conduit and exposed after the crater collapse.

The morphology of the crater prior to the opening of the harbour is masterfully depicted in the topographic plan drawn by Carlo Vanvitelli around 1792 and in the historic map of 1840 (Reale Ufficio Topografico di Napoli 1840, source IGMI). The latter also supplies some land use features. At that time the whole area was sparsely inhabited, except for the small village of *Villa dei Bagni e della Casina*

Fig. 7 View of Ischia lake, Philip Hackert (1792). Palazzo Reale Caserta (from De Seta 2005)

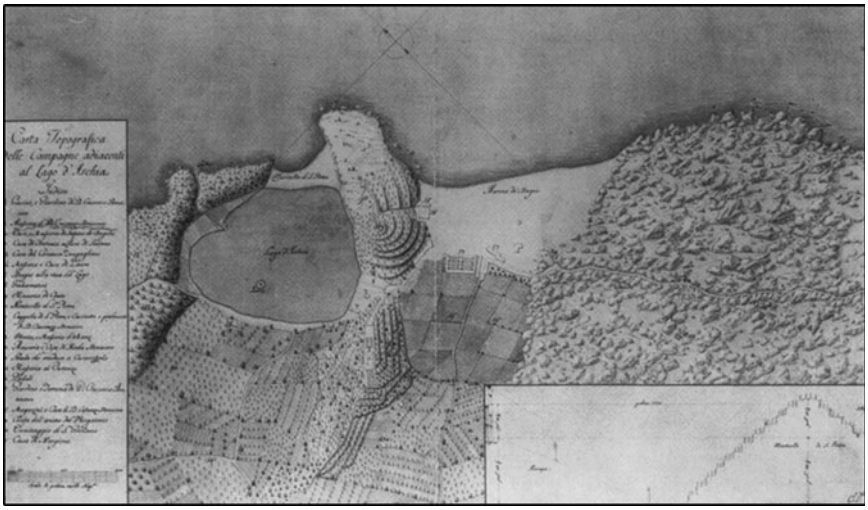

Fig. 8 An antique topographic map of the *Lago del Bagno* and neighbouring countryside. A sandy isthmus separates the lake from the sea in the north. A little channel in the western side allowed the water to circulate between the lake and the sea. In the southern sector of the lake a small lava block crops out (Vanvitelli 1739–1821) (from Delizia and Delizia 2006)

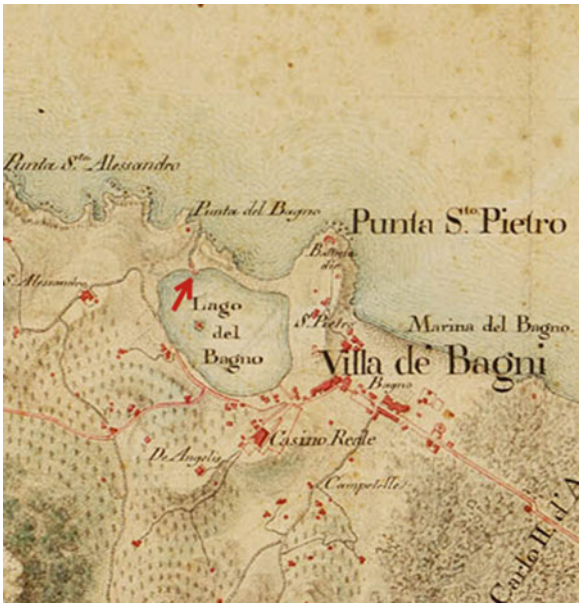

Fig. 9 Topographic map of the Royal Topographic Office of Naples, scale 1:25,000, 1840 (IGMI source). On the left sector of the lake (sea side) the little channel for water circulation (*arrow*), in the eastern and southern sector the Villa dei Bagni settlements and the Royal Lodge (Casino Reale), respectively. The whole area around the future harbour was formed by cultivated fields and woods

Reale. The lake was surrounded by woods and plots for growing fruit and vegetables. In both maps the small channel communicating with the sea can be recognised, situated westward (Figs. 8, 9). This channel was opened in 1670 to

prevent the lakeside shores from becoming marshland due to the presence of hot-water springs and the depositing of current-borne marine vegetation during storms at sea (Quaranta 1855; Delizia 1987; Minervini 2004). Indeed, winter storms carried beyond the narrow sand dune a large quantity of *posidonia* (sea-grass) which rotted during the summer, producing a typical smell of sulphur. The channel mouth was kept closed by a series of reed gates, which permitted a change of water, while the retained fish quietly prospered in the lake.

Towards the mid nineteenth century the island became a site of extreme interest for scholars of volcanology and seismology, in a cultural climate in which scientific debate became lively. Of the products generated by this period of scientific enquiry mention should be made of the production of the first geological map of the island of Ischia, at a scale of 1:25,000, by Ferdinando Fonseca (1847), associated to the French Geological Society (Fig. 10). It is not a real geological map in the modern sense of such cartography, as it lacks some elements on the succession of eruptive events on a stratigraphic and structural basis. Rather, it is an areal subdivision of the most widespread lithotypes on the island. Fonseca distinguished four types of outcrops: trachytes; tuff and incoherent volcanic material; sub-Apenninic marl; quaternary shell aggregates.

In 1873, Fuchs proposed a geological map of the island of Ischia, again at the scale of 1:25,000 (Fig. 11) (Fuchs 1873). There are two curiosities here. First, the

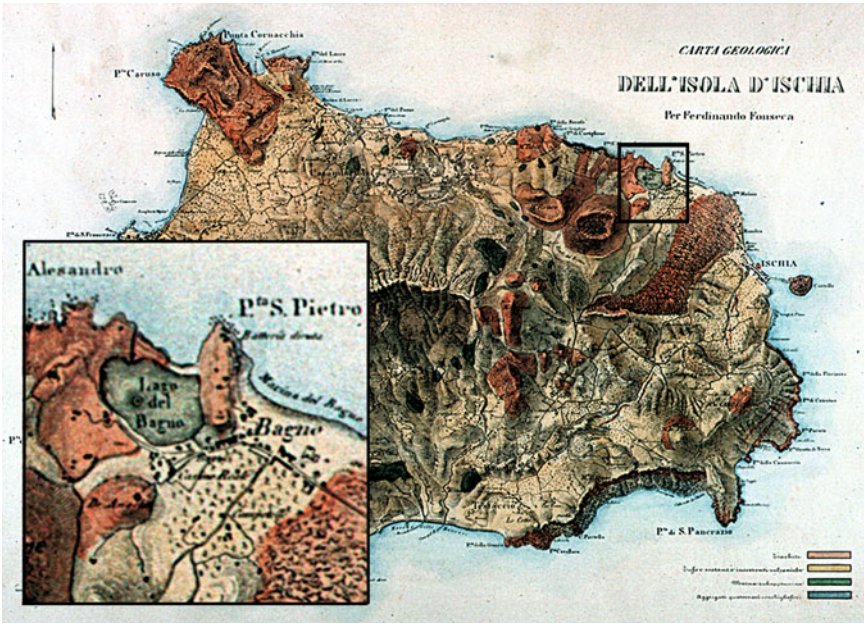

Fig. 10 First geological map of Ischia produced by Fonseca (1847), scale 1:25,000. The most recent lava flow and lava and scoria cones are represented in red-brown. Inset with a close-up of the *Lago del Bagno* zone

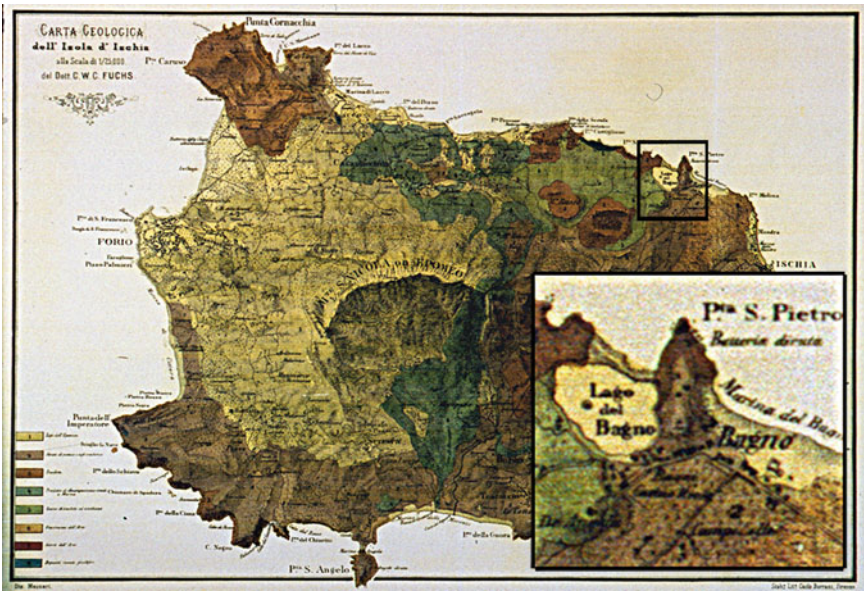

Fig. 11 Geological map of the island produced by C. W. C. Fuchs, scale 1:25,000. The map is dated after the harbour opening (1873). As highlighted in the square, the isthmus separating the lake from the sea is still present. Thus it is likely that the topographic map utilized by Fuchs is the same as that used by Fonseca (1847)

town called *Ischia* corresponds to the present-day Ischia Ponte close to the castle; secondly, the map does not show the cut in the isthmus which occurred in 1854 with the opening of the harbour in *Lago di Bagno*. It may be deduced that the basis for Fuchs's map was the same as that used by Fonseca. Fuchs's geological map was published in Volume II of "Memories serving to describe the geological map of Italy". This may be considered the first geological map published by the geological Royal Committee established by decree of Victor Emanuel II on 15th December 1867 and according to standards laid down by the Royal Decree issued 15th June 1873.

For Fuchs, the considerations made by Fonseca only partly apply, in that he distinguishes the temporal succession of the various outcropping products: in this new map Fuchs believes that the Epomeo tuff is the most ancient outcrop, above which rest layers of pumice, tuff and lava flows produced by the various eruptive centres on the island. Fuchs distinguishes eight types of outcrops: Epomeo tuff; flows, domes and cones of trachytes; products of a similar composition to marl; scoria of trachyte and obsidian; the Arso layer; Arso scoria; recent fossiliferous deposits. In both the geological maps of Fonseca and Fuchs, there is clear documentation of the sand bank that separated *Lago del Bagno* from the sea, the volcanic edifices of Montagnone and Rotaro, the Arso lava flow eastward and the morphology of the whole future harbour area.

4 The Opening of Ischia Harbour

Ferdinand II was personally very fond of the island of Ischia. Together with his second wife, Maria Theresa, and their many offspring, he spent several months there every year, relaxing by the *Lago dei Bagni*, in the Royal Lodge that dominated its shoreline from the hill nearby (Minervini 2004). When the King arrived, he said: "…of the lake we shall make a harbour, it will be the lifeblood of Ischia". As often happened during the Bourbon period, the vacation macro-project idea swiftly became reality. Its purpose was twofold: increase the consensus for Bourbon initiatives to renew the kingdom and transfer their own representative on the island from the castle to those delightful, unspoilt places. This was the necessary step to carry out the "Royal Delights" project which the same Ferdinand II completed with the conversion of the Buonocore residence into a Royal Lodge, with the construction of the Church of Portosalvo and the restoration of the royal space adjacent to the whole area of the future port (Delizia 1990).

The Provincial Council of Naples turned down the planning application from the Council Authority of Ischia to build the harbour, since the intervention was not deemed useful and the island *not susceptible to development* (Rispoli 2007). On 13th March 1853 the far-sighted King Ferdinand II, convinced of the importance of the work, overrode the decision and passed a decree to make the lake into a harbour for Ischia. Although the initial estimate was 50,000 ducats, modifications when the project was under way made the cost climb to over 126,000 ducats, a considerable sum in those times. By 25th July of the same year the works had already begun, and they were completed in only 14 months, a relatively short period of construction time given the resources and technology at their disposal (Annali Civili del Regno delle Due Sicilie 1855).

From the preliminary analysis of the lake's characteristics, commissioned by the king, we have the first information on the nature and economic quantity of the works to be undertaken. The latter involved the removal of part of the sandbank separating the lake from the sea to the north, with an entrance of $\sim$500 palms ($\sim$130 m). A jetty was also to be constructed to protect the harbour mouth from the strong NNW winter winds, about 700 palms long ($\sim$182 m) consisting of about 541 cubic *canne* ($\sim$10,000 m^3) of rock obtained from a cliff beyond the small river mouth to the west, and the bed was to be dredged to allow access for large vessels as well (Archivio di Stato di Napoli, Ministero dei Lavori Pubblici 1853–1854). The whole lake-bed was excavated, removing material about one metre deep, amounting to 115,000 m^3. To enable these operations, on 31st May 1854 the King commanded a small specialised fleet to be transferred, consisting of two steam dredgers, a small steamship, and a four-boat tug to protect the harbour entrance (Quaranta 1855; Carelli 1858; Rispoli 2007). In addition, an ancient water/debris collection tank situated near the Buonocore residence that was blocked would be emptied, so as to prevent storm-related flooding caused by streams to the south invading the lake-bed, making safe navigation more difficult.

The macro-project for constructing the harbour was assigned to the Inspector of Bridges and Roads Luigi Oberty and Lieutenant Domenico Milo of the Engineering Corps, while the project's director was Camillo Quaranta, a commissioner of the Royal Navy. The latter left behind copious documents concerning the state of the works, which point out the difficulties encountered in the work, the mishaps and some technical details on intervention topologies (Delizia 1987). Before embarking on the sand removal works, Quaranta first strengthened the lake shores with walls supported on robust iron frames. He then built further embankments to flank the short channel entrance opening to the sea and raised the quay for moorings (Quaranta 1855; Minervini 2004). The cutting and removal of the sand bank to open up the channel to the sea was completed 4 months later. The works in progress are beautifully depicted in a painting by Francesco Mancini (1830–1903), which shows the building site with the channel to the sea already open (Fig. 12). King Ferdinand II was not ever present during these operations, but waited for the work to be completed, on 31st July 1854, before entering for the very first time aboard the Royal Steamship *Il Delfino*. It was a sort of technical test and verification of the works prior to the official inauguration held on 17th September. The news was reported in the *Giornale delle Due Sicilie* as an event of worldwide importance and enthusiastically feted by the population of the whole island. The inauguration occurred amidst the boom of discharging artillery, the lyrical notes of several musical bands, the charitable sounds of the excited throng of pleased islanders decked out in party costumes and about 200 ships and boats. The parade

Fig. 12 The gouache by F. Mancini (1853) reproducing the works during the opening of the isthmus separating the *Lago del Bagno* from the sea (Private Coll.) (from Caputo 2000)

of vessels was preceded by the Royal Launch, followed by the warships *Tancredi*, *Saetta*, *Delfino* and *Antilope*. Thus began a new era for Ischia, in which the harbour played a key role in changing both the island itself and relations between the island and the mainland (Quaranta 1855; Mirabella 1913).

Works to improve the structure of the harbour continued for about 2 years. At the end of the protective breakwater on 15th December 1856 a fifth-order lighthouse was first lit. For ships arriving from the northeast, Ischia Harbour lighthouse, together with the smaller warning light from the nearby island of Procida, represented an important reference point for coastal navigation in the channel that separated the two islands from the Italian mainland. Southward, instead, Ischia lighthouse with that of Capri, about 21 miles to the south, would be very useful for large vessels sailing to and from the islands of Sicily and Malta. Works to redesign the harbour area were completed with the construction of the church of Santa Maria di Portosalvo in 1856, crowning the programme of Ferdinand II of the Royal Delights of Ischia in the last few years of his reign (Rispoli 2007; Delizia 2007a, b).

Ischia Harbour, therefore, played a fundamental part in opening the island towards the sea and the mainland, allowing new trading and cultural links, further increasing spa and recreational tourism, supplying a new structure to the island in which the harbour became the pivot for the island's social and demographic growth (Fazio 1896).

From 1943 to 1945 the harbour played a role of vital importance as an Allied naval base in the Mediterranean Sea Basin, taking its cue from what was happening on the mainland in the regions of Campania and Lazio, a few miles away from the island (Silvestri 2004). In the years after the Second World War the

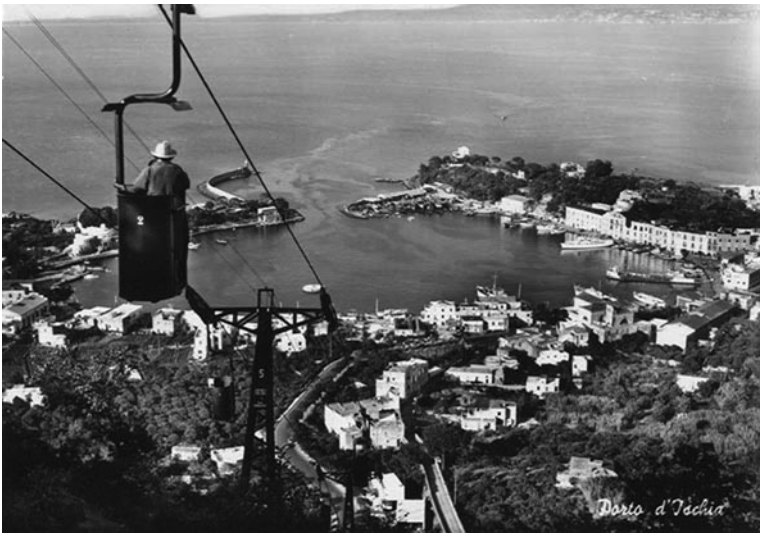

Fig. 13 Ischia Harbour in the 1950s with the old cableway (postcard of the island)

Harbour of Ischia still retained all its splendour (Fig. 13) (Taddeo 1954). However, the post-war subsequent economic boom and increase in tourism were to change the area progressively, resulting from excessive population pressure. This was to lead to a gradual covering/sealing of the transformed natural landscape by the distinctly man-made landscape. However, the volcanic structure of this region is still predominant; its natural evolution must be taken into account when assessing the island's future economic and population development scenarios. Ischia Harbour is deep enough today to navigationally accommodate rather large motorized and sail-driven ships.

5 Recent Geological Studies of Ischia

The island of Ischia, located at the margin of the Bay of Naples, has an area of 47 km^2 with 34 km of coastline. It is formed by volcanic rocks (pyroclastic flow and fall, lava domes and lava flows) from eruptive centres largely destroyed or covered by subsequent activity. The oldest volcanic activity dates back about 150 ka BP while the most recent eruption occurred in 1301–1302 (Fig. 14).

In recent times geophysical, geological and volcanological studies have been performed to gain insights into the volcano-tectonic dynamic of the Campanian volcanic district, also including the island of Ischia (Cubellis and Luongo 1998; Judenherc and Zollo 2004; Carlino et al. 2006; Berrino et al. 2008; Paoletti et al. 2009; Sbrana et al. 2009; Vezzoli et al. 2009; de Vita et al. 2010). Many of these studies agree with the hypothesis, first proposed by Rittmann (1930), that volcano-tectonic processes of the island are linked to the occurrence of a shallow magmatic intrusion (about 2 km deep) beneath its central sector. This intrusion probably took place after the large ignimbrite eruption which occurred about 55 ka ago, with emission of 20–45 km^3 of pyroclastic flow, pumice flow and ash-fall deposits, called Mt. Epomeo Green Tuff (MEGT). This eruption produced a sub-circular caldera collapse, about 10 km × 7 km wide, which underwent a process of resurgence, starting about 33 ka ago (Vezzoli 1988), and formed the uplifted structure of Mt. Epomeo (787 m above sea-level). The edges of the uplifted Mt. Epomeo block are marked by a system of faults and fractures (Vezzoli 1988; Fusi et al. 1990; Orsi et al. 1991; Luongo et al. 1995; Cubellis and Luongo 1998; Tibaldi and Vezzoli 1998, 2004; Carlino et al. 2006; Sbrana et al. 2009). The average uplift of ~800 m, deduced by the present-day height of marine deposits on Mt. Epomeo, occurred as a discontinuous process, until 5 ka BP, at an average velocity of about 3.3 cm $year^{-1}$. During the last 10 ka the geological history of the island was also punctuated by the occurrence of large-scale avalanching processes, producing the dismantlement of the southern slope of Mt. Epomeo between 8 and 5 ka (Vezzoli 1988; Tibaldi and Vezzoli 2004; Luongo et al. 1995; Carlino and Cubellis 2005; Carlino et al. 2006, 2008; Luongo et al. 2008, 2009).

The seafloor around the island shows an articulate morphology due to volcanic, tectonic and erosional marine geomorphologic processes. Many shallow banks,

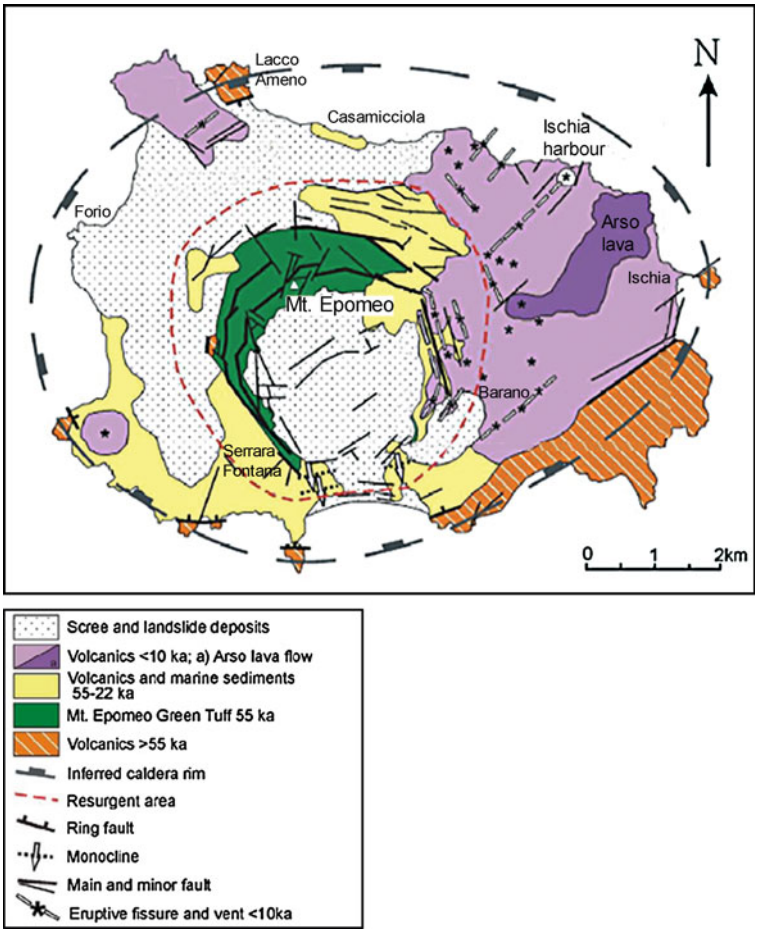

Fig. 14 Geological map of the island with the main tectonic features. Two relevant structures are drawn: the Green Tuff caldera and the resurgent area of Mt. Epomeo (modified after Vezzoli et al. 2009)

which are the result of submarine volcanic activity, are located around the island at shallow depth. The southern part of the sea-bottom is riven by different canyons, the largest of which lies on the main tectonic alignments of the area. The continental shelf is well developed in the northern part of the island with a slight descending slope, while the southern part has a marked shelf break very close to the coastline. Another remarkable feature of the sea-bottom around the island is the presence of large debris deposits resulting from the avalanching processes which involved the slope of Mount Epomeo (Chiocci and De Alteriis 2006). The largest of these underwater debris deposits is located in the southern part of the island where a typical "hummocky topography" is observed at a depth of 600

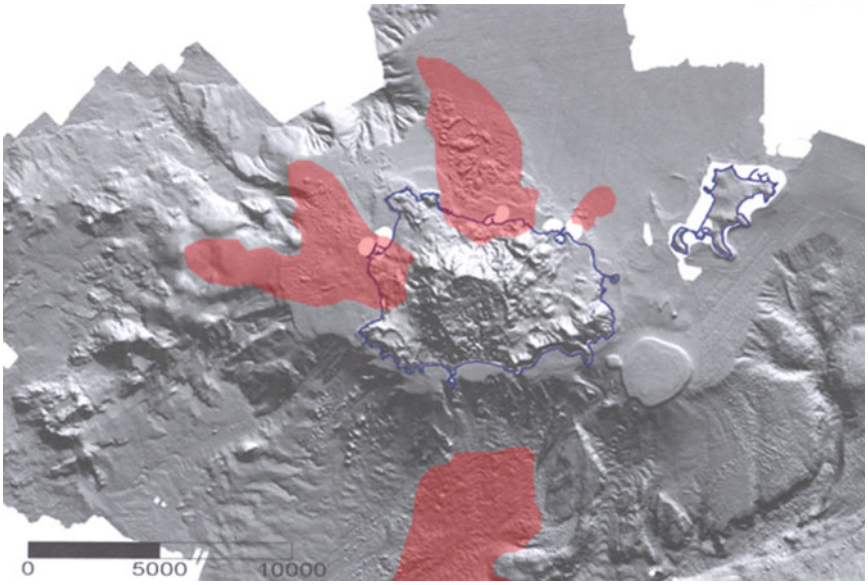

Fig. 15 Digital Terrain Model (DTM) of emerged and submerged area of Ischia volcanic field. The different slope of the scarps in the northern and southern sector is evident. The red zones represent the main debris avalanche deposits whose source has been identified on the island. To the right the island of Procida (modified after de Alteriis et al. 2006)

to 100 m below sea-level, while only minor landslides have involved the continental shelf in near the entrance to Ischia Harbour (Fig. 15).

5.1 The Recent Sub-surface Dynamic

The sequential time history of eruptions in the island can be obtained from 150 ka BP up to the last great eruption in AD 1301–1302 with lava flow in the eastern sector. Instead, the data on the earthquakes are usually reliable only from the thirteenth century onwards. From that time, many earthquakes devastated the northern part of the island; the strongest, and latest, major earthquake occurred in 1883 (Imax = XI MCS degree), producing severe damage and 2,333 victims. Afterwards, a low level of seismicity was observed on Ischia (Cubellis and Luongo 1998; Cubellis et al. 2004; Luongo et al. 2006; Carlino et al. 2009).

Presently, a diffuse hydrothermal system, with fumaroles and hot-springs with maximum surface temperatures of $\sim$100°C, is recognizable around the resurgent block of Mt. Epomeo, while submerged archaeological ruins near the existing coastline, and levelling data since the early twentieth century testify to a general subsidence of the island (Luongo et al. 1987; Pingue et al. 2005; Manzo et al. 2006; De Martino et al. 2007). A low subsidence rate (few millimetres/year) can be

linked to the stasis phase of the shallow magma body dynamic below the surface of the island.

5.1.1 The Geology of Ischia Harbour

The crater of Ischia Harbour was formed several centuries BC. The volcanic products in the eastern sector (San Pietro Hill) overlie a palaeosol developed on top of an older trachyte containing pottery remains from the fifth century BC and roof tiles of the sixth to fifth centuries BC (Buchner 1986; Vezzoli et al. 2009) (Fig. 16). The Ischia Harbour crater was formed by a phreatomagmatic eruption, during which the explosive energy increased, followed by a magmatic phase with a strombolian activity (Fig. 17a, b). A small positive gravity Bouguer anomaly (Maino and Tribalto 1971), close to the harbour, highlights the presence of a shallow dense mass which can be interpreted as due to the solidified lava lake formed during the last phase of the eruption (Fig. 18). This interpretation is supported by the presence of a rock block emerging from the lake surface.

What remains of the Ischia Harbour eruptive centre is a sub-circular crater ~400 m across in diameter, located along a NE–SW eruptive fissure. The related products are composed, from bottom to top, of stratified tuffs, black scoriae,

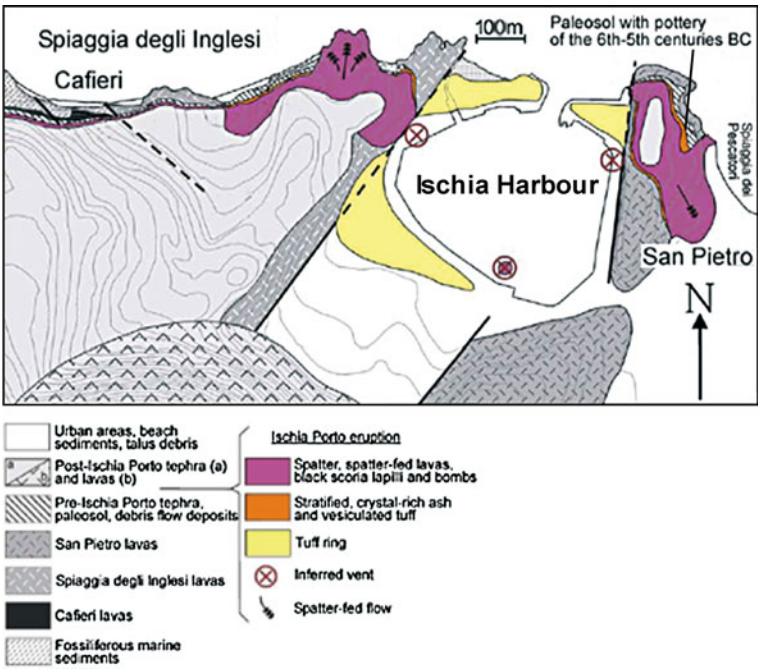

Fig. 16 Geological map of Ischia harbour (modified after Vezzoli et al. 2009)

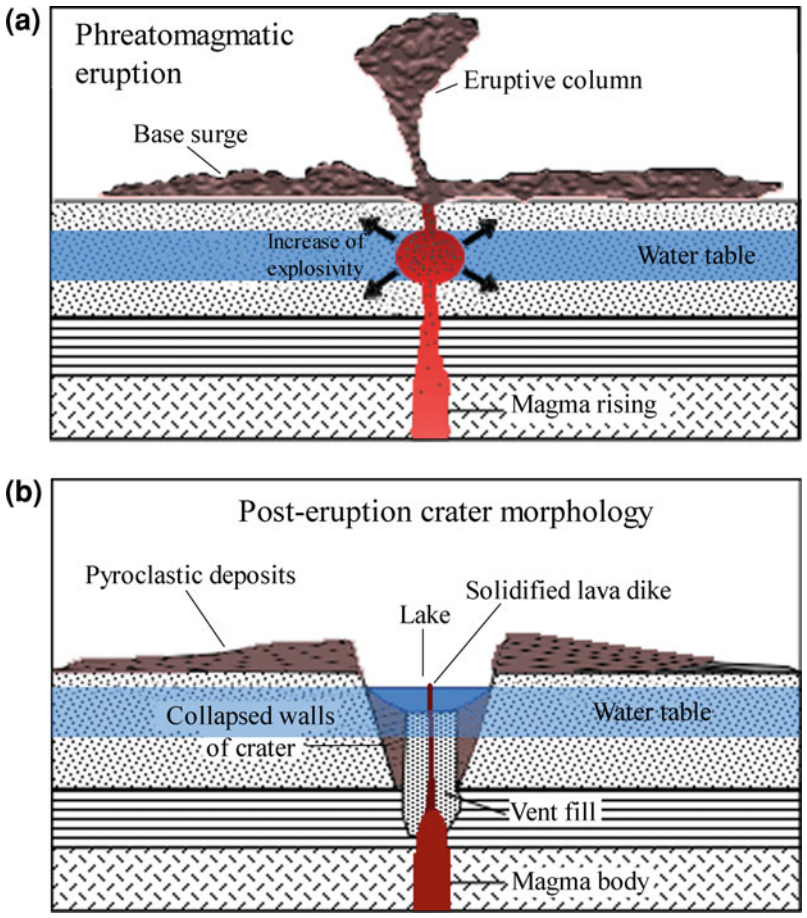

Fig. 17 Sketch of the formation of a crater like Ischia Harbour (maar-type). This is formed after small phreatic eruptions during which the magma comes into contact with water and increases its explosivity (**a**). After the eruption a moderate collapse of the crater occurs, while the lava which has feed the eruption solidifies forming a dike; the volcanic depression is refilled by the water (**b**)

spatters and spatter-fed lavas. The basal unit shows cross laminations and abundant lithic content, which suggests a pyroclastic surge origin due to phreatomagmatic explosions. During the eruption, fire-fountains probably generated the scoriae and spatter deposits located along N–S and NE–SW-striking fracture within the Ischia Harbour crater. The internal and external slopes of San Pietro hill, to the east, and the Spiaggia degli Inglesi marine cliff, to the west, are mantled by stratified tuffs, scoriae, and spatter deposits. The external slopes are characterised by the presence of, spatter bombs welded together and flowed, ballistic lithic blocks and accretionary lava balls (Vezzoli et al. 2009) (Fig. 16).

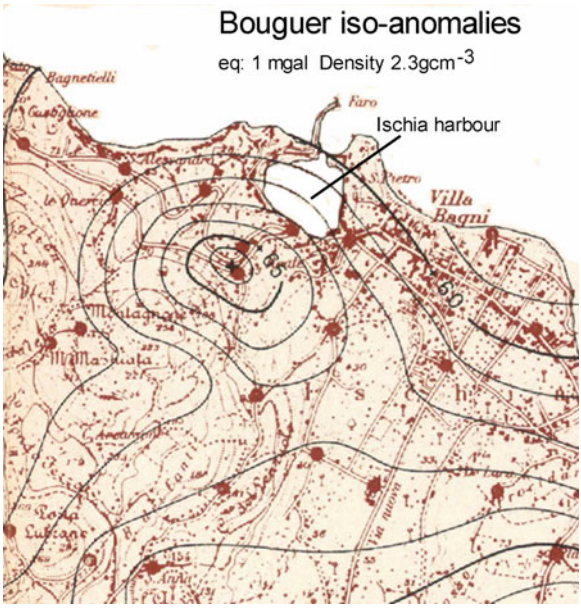

Fig. 18 The positive Bouguer anomaly inferred from the gravimetric survey of the island, interpreted as the occurrence of a shallow magmatic body very close to the harbour area (modified after Maino and Tribalto 1971)

On the west side of the harbour, the oldest unit comprises volcanogenetic sediments composed of stratified, fossiliferous sand and ashy silt. The fossil content indicates a palaeo-bathymetry between 50 and 80 m below sea level, dating from 9,800 to about 6,400 years ago (Barra et al. 1992; Vezzoli et al. 2009). At present, these sediments are uplifted up to 50 m, testifying to a minimum uplift of about 100 m during the last 10 ka.

The most recent coastline variation of the harbour area is exemplified by the presence of archaeological ruins on the land close to the crater. These finds are also located along the coastline in the eastern sector of the island (Castello d'Ischia), in the north-western and western part (Lacco Ameno and Forio) and in the southern as well (Sant'Angelo). The finds have been dated between the fourth century BC and second AD, and consist of Greek and Roman walls, and the remains of thermal baths and pools (Buchner 1965). They provide evidence for the general subsidence of the island since they are commonly located 1.5–2 m below the present sea level; thus an inversion of the ground movements occurred, later than the Roman period; Friedlander (1938) using a tide-gauge measured a subsidence velocity of 3.4 mm year^{-1}. Taking into account this value and the depth of the ruins two hypothesis are possible on the subsidence: in the first the subsidence started in the first century AD, but its velocity during the last 2000 years was far less than that observed by Friedlander; alternatively, in the second the subsidence started a long time later than the Roman period.

Nowadays two tide-gauges, which belong to a wider network for sea-level monitoring in the Bay of Naples, operate on the island, at Ischia and Forio harbours. The data are also utilised for slow ground deformation monitoring related to the dynamic of Neapolitan volcanoes (Capuano et al. 2004).

6 The Island of Ischia: Development and Natural Risks

Since 1854, when the harbour was opened up, the island has undergone far-reaching changes in terms of its economy, society and land use. The Harbour at Ischia has become a major tourist destination besides the main point of access to the island: its shores have been radically changed by human intervention and by a development policy chiefly focusing on increasing the building meterage (Luongo et al. 2006) (Figs. 19a, b, 20). In the Ischia municipality the resident population has more than doubled since the early 1800s (ISTAT 1861–2001) and the relative urban expansion has failed to take account of the knowledge acquired of natural phenomena occurring on the island and especially their possible effects upon the region (Luongo et al. 2006). After all, the island has an active volcanic dynamic, and is affected by seismicity, chiefly in the northern sector, and has a high predisposition to landslides and floods on land (Luongo 2009; Carlino et al. 2010).

In this context, the remarkable recent urbanisation on the island and the lack of planning that accentuates the vulnerability of the region has produced an exponential increase in geological risk. Previous visible eruptions, felt earthquakes and uncontrolled freshwater flooding on the island of Ischia have produced a wealth of literature on such catastrophic natural hazard events. In general, these events are recorded in such disparate fashion, as in newspapers, in reports of property boundary and damage disputes, historical and sociological analysis, poetry and artistic works and some published scientific analysis (Cubellis and Luongo 1998, and references therein).

Eruptions, earthquakes and tsunamis have been recorded in myths, legends, demonstrated by archaeological finds, described in historical documents and the results of recent scientific and engineering surveys. Documented descriptions of

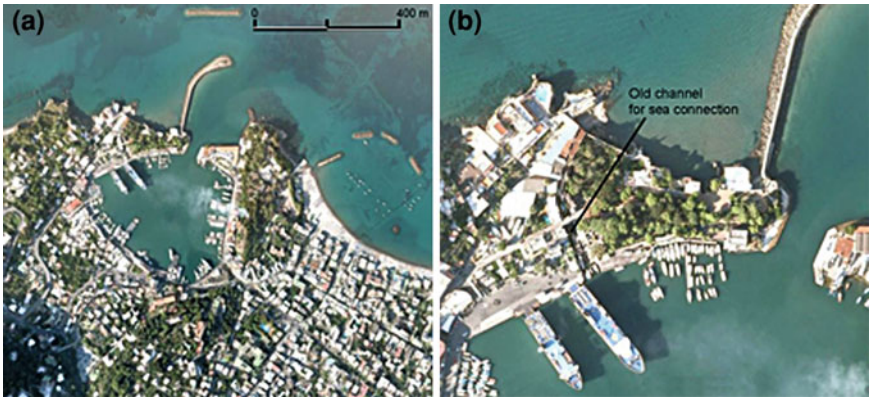

Fig. 19 Ischia Harbour today (**a**); the considerable urbanization of the area is evident. The old channel for the circulation of the water can still be made out, though it has turned into a cement structure (**b**) (from Google Earth)

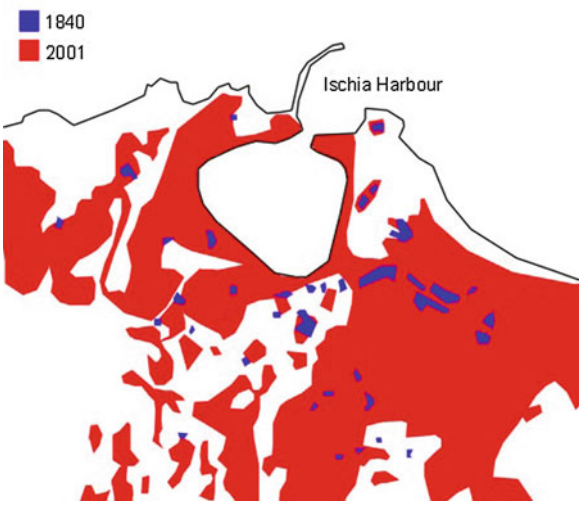

Fig. 20 A comparison between settlements around Ischia Harbour in 1840 and 2001. A huge increase in built-up areas has occurred, with a consequent increase in exposure and volcanic and seismic risk

historical eruptive events are only available for the last eruption of 1301–1302, while there are records for eruptive events in the early centuries AD. More comprehensive accounts are available about historical seismicity. Information and documentation have been available since the 1228 earthquake. However, more detailed, useful interpretations of earthquakes concern events from the end of the eighteenth century. There is an almost inexhaustible literature related to the 1881 and 1883 earthquakes, pointing out the relationship between seismicity and the volcanic history of the island. These two seismic events occurred during an intense period of production of geological maps and fieldwork study on the island's physical characteristics. The effects of the earthquakes were classified using the former scale of intensity, and different mechanisms of the seismic source were suggested (Luongo et al. 1987; Cubellis and Luongo 1998; Luongo et al. 2006).

The earliest information on hydrogeological disasters on the island dates back to the sixteenth century when major floods affected the island during extreme local weather conditions. An archetypal phenomenon was the 1910 flood which caused serious property damage and remarkable changes in morphology of the areas directly affected by the sudden inundations. In recent times (for example, AD 2006 and 2009) floods scourged the island again, producing debris flows which devastated its northern sector, resulting in human injuries, some few fatalities and remarkably heavy damage to the island's infrastructure.

Analysis of catastrophic events on the island occurring during historical times shows, in synthesis, that its northern sector was the region affected by the heaviest earthquake and flood damage. This condition is caused by the region's tectonics and morphology, as highlighted by the integrated analysis of structural data and seismicity.

Although in recent times our knowledge of the island's geological phenomena has improved, and special attention has been laid on the effects of their most

intense manifestations and related risks, regrettably among the unwary communities exposed to environmental risk few people have adopted the culture of preventive action. In light of this fact, the level of attention to extreme geological phenomena apparently only grows in concomitance with catastrophic events, while political decision-makers limit themselves to intervening only in the emergency phase, without any long-term programming of responsible land-use management policies to ensure the future reduction of geological risk. This situation becomes hard to macro-manage when, faced with the recurrence of entirely natural phenomena capable of instigating very significant damage to property and inducing tragic loss of human life, there is still the dogged continuation of illegal building, which has during the early twenty first century produced a level of risk to residents and visitors that is no longer really acceptable by a truly modern society.

7 Conclusions

The opening of Ischia Harbour in 1854 was undoubtedly an intervention which radically changed the hierarchical relations between the island and the mainland. It is also a fine example of the art of nineteenth century macro-engineering (Rispoli 2007). It was an operation which, in terms of techniques and execution times, was certainly ahead of its time. Although the reasons that drove King Ferdinand II to open up the pre-existing Bagno Lake, to make it the island's main port, were chiefly personal, what lay behind the choice was the spirit of renewal in regional policies, which was one of the hallmarks of the Bourbon government. At that time the island was already well known for treatments with its thermal waters, especially in Casamicciola, where since the late sixteenth century many visitors had gone to enjoy their therapeutic effects. However, the lack of safe harbours throughout the island made access difficult, especially in winter months when the frequency of sea storms increases considerably. With the opening-up of Ischia Harbour, the situation radically changed: maritime traffic and the flow of visitors shifted towards the eastern side of the island which thus became easily accessible, also for large steamships. The new centre of life on Ischia would become endowed with further improvement works, especially on the road network, which—together with the very presence of the harbour—was to generate a population increase in the *comune* of Ischia, rather than elsewhere on the island, and lead to new urban settlements.

The natural features of the harbour, obtained from an ancient crater lake, are certainly singular. However, its so well-defined shape has prevented its expansion (Rispoli 2007), which would seem necessary to handle the substantial increase in maritime traffic. Hence the morphology of the ancient lake poses a constraint to expanding today's port. Today, its navigational depth is <10 m. Maritime traffic can only be regularised on Ischia through a strategy to improve the efficiency of port services and passenger vessels. During the peak tourist season more than 20 large vessels dock and sail daily, handling about 15,000 passengers, and over 35

fast-ferry watercraft handling 8,000 passengers, making a total flow of 23,000 passengers per day. It is some surprise that, in 1853, the Provincial Council of Naples failed to approve the construction of the new harbour of Ischia, which it considered a site "unsusceptible to development". Clearly, for such regions endowed with natural, untamed landscape and cultural attractions, interventions resulting in better accessibility and fruition produce not only an increase in tourist traffic, but also proliferation in the resident human population. Moreover, as the island economy's organisational centre, the Harbour brings about the transition from settlement of the coastal zone to that of the inland zone. The trade taking place in the market-harbour promotes a deep-rooted conversion of production, from a closed, internalized intra-consumption economy to an inter-regional trade economy (Vella and Barbera 2001). In this sense, Ischia Harbour represented not only a window looking to Italy's mainland but also a key factor in the island's social and cultural aggregation.

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