International Journal of Coal Geology 132 (2014) 13–22

Contents lists available at ScienceDirect

International Journal of Coal Geology

journal homepage: www.elsevier.com/locate/ijcoalgeo

Lignite resources of Turkey: Geology, reserves, and exploration history

Volkan Ş. Ediger [a,*], Istemi Berk [b], Ayhan Kösebalaban [c]

[a] Kadir Has University, Kadir Has Street, Cibali, 34083 Istanbul, Turkey
[b] Institute of Energy Economics, University of Cologne, Vogelsanger Str. 321, 50827 Cologne, Germany
[c] Turkish Coal Enterprises (TKİ), Hipodrom Cad. No. 12, Yenimahalle, 06330 Ankara, Turkey

ARTICLE INFO

Article history:
Received 27 February 2014
Received in revised form 4 June 2014
Accepted 10 June 2014
Available online 17 June 2014

Keywords:
Lignite
Geology
Reserve classification
Exploration history
Turkey

ABSTRACT

This article aims to emphasize the importance of lignite, which is the mostly used domestic energy source in the Turkish energy mix, by briefly overviewing its geology, reserves, and exploration. Lignites are distributed in mostly continental sedimentary basins of Tertiary age all over the country. The lignite-bearing basins display the characteristics of different geological settings, of which grabens and half-grabens are the most common ones especially in western Anatolia. The geological and chemical characteristics of Turkish lignites do not only create some important problems during mining and coal preparation but also make them unfavorable for consumption. However, since they are the most valuable energy resource of the country they should benefit the economy in the most efficient and environmentally friendly way. Moreover, two most important conclusions of this study are as follows: firstly, reserve estimation practices in the country should definitely be revised to provide a more realistic evaluation of the country's lignite potential for developing medium- and long-term energy strategies and policies for decision- and policy-makers. Secondly, exploration and development activities should be coordinated by a single institution, most likely a government institution, as has been the case for some 50 years.

1. Introduction

As the major indigenous energy source of the country, lignite, constituting up to 20.9% in 1986 of the energy mix of Turkey, has always been very important. Recently, although its share is increasing from a historical minimum of 10.2% in 2005 to 14% in 2012, the share of hard coal has almost doubled by increasing from 8.8% to 16.7% between 1978 and 2012, making it more important than lignite. However, lignite is the biggest national energy resource whereas hard coal is import-dependent at the rate of 94.7% by 2012. This is a very controversial policy for a country whose dependency on foreign energy sources has already reached 75.9% by 2012. This article, therefore, attempts to emphasize the importance of lignite as the major domestic energy source in the Turkish energy mix by briefly overviewing its geology, reserves, and exploration.

The upstream sector of the Turkish lignite industry is traditionally dominated by state-owned enterprises, such as the General Directorate of Mineral Research and Exploration (MTA), the General Directorate of Turkish Coal Enterprises (TKİ), and Electricity Generation Company (EÜAŞ). However, while TKİ and EÜAŞ are responsible for lignite production and electricity generation from lignite, MTA was established to conduct reconnaissance, appraisal, and exploration activities for coal among other minerals. For this reason, most research and exploration activities, including geological mapping, geochemical analyses, geophysical studies, exploratory drilling, etc. have been carried out by MTA since its establishment in 1935. However, after the establishment of TKİ in 1957 and TTK (Turkish Hard Coal Enterprises) in 1983, some of MTA's duties have been transferred to these enterprises. After it was delegated responsibility for the lignite fields feeding coal-fired power plants, EÜAŞ became not only the second biggest lignite producer after TKİ, but also the public company with the largest lignite reserves in Turkey especially after 2005.

Since TKİ has historically been the major lignite supplier to industry, this study concentrates on its reserves and upstream activities. The relevant activities of other state-owned enterprises and private companies are also included wherever data is available. The data presented in this study is mostly obtained from TKİ within the framework of the project "History of Turkish Coal Enterprises (TKİ) and Turkish Hard Coal Enterprises (TTK), and Turkish Coal Strategies". Other data including previous reports and publications are also used in various extents. Therefore, unless otherwise stated the data is from Ediger (2014).

Although they can also be traced back to the late 19th century, modern and well-documented lignite exploration activities started in the 1970's as summarized in TKİ (1973). From this perspective, *Lignite Inventory of Turkey* published in 1986 has been a milestone as far as geology and reserves of Turkish lignites are concerned. The report

* Corresponding author at: Kadir Has University, Energy Systems Engineering Department, Kadir Has Street, Cibali, 34083 Istanbul, Turkey.
E-mail address: volkanediger@gmail.com (V.Ş. Ediger).

http://dx.doi.org/10.1016/j.coal.2014.06.008
0166-5162/

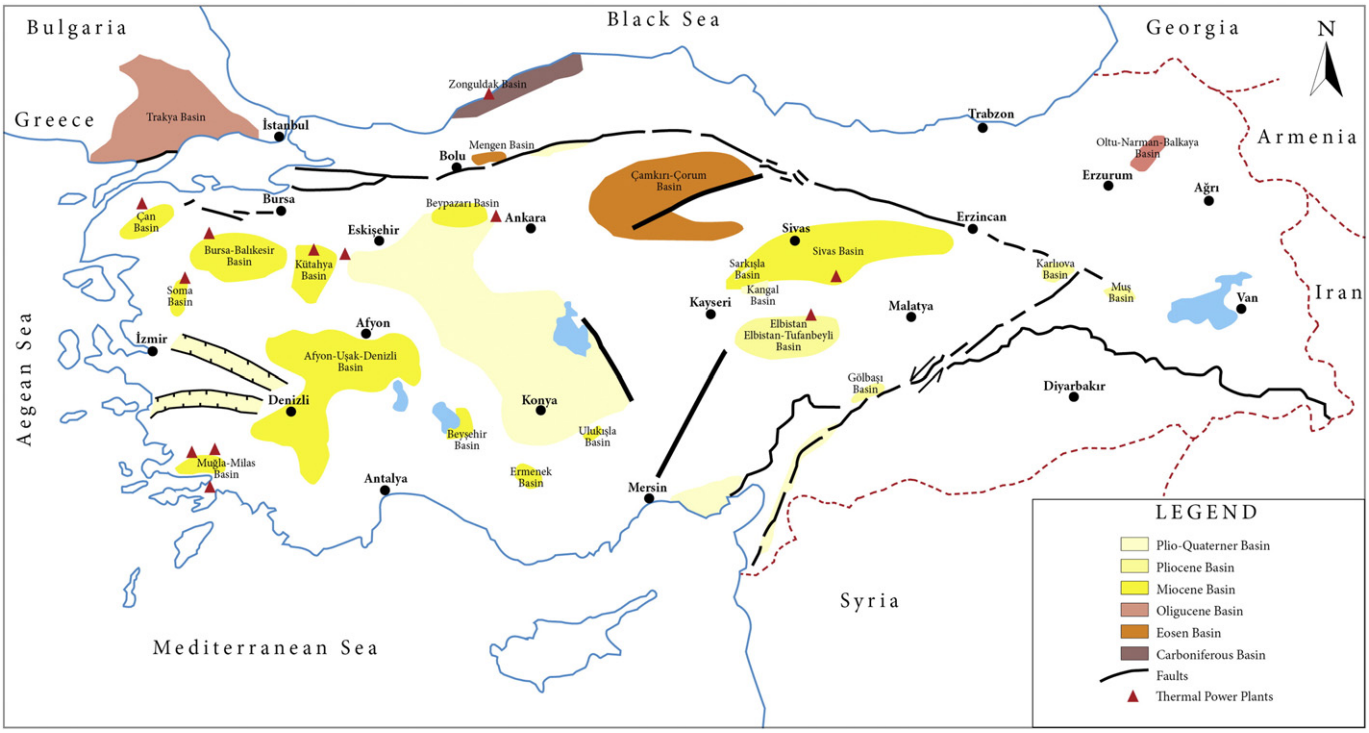

Fig. 1. Coal basins of Turkey. Compiled from the Map of "Tertiary Coal Basins of Turkey" prepared by MTA[2]

[2] Available at: http://www.mta.gov.tr/v2.0/daire-baskanliklari/enerji/images/siteharitalar/5.jpg. Access date: 23.12.2013.

prepared by a special commission established in MTA compiles all previous studies and evaluates a total of 133 lignite occurrences in Turkey systematically (MTA, 1986). Data presented in this report and in its revised forms has been used by policy makers and investors for many years.

The second important year in terms of lignite exploration was 1993. MTA revised its inventory (MTA, 1993), and MTA and TKİ geologists presented several papers in the *Symposium on Our Lignite Sector Towards the Years 2000's* organized by the Turkish Chamber of Mining Engineers (TCME, 1994). Finally and more current, MTA revised its inventory for the third time (MTA, 2010); TKİ published its *Lignite Sector Report* (TKİ, 2011), and Ünalan (2010) summarized all available data in a MTA book entitled *Coal Geology*. Meanwhile, a group of MTA geologists headed by Ertem Tuncalı compiled all previous data in a book entitled *Chemical and Technological Properties of Tertiary Coals of Turkey* (Tuncalı et al., 2002). In addition to all these, "Lignite Exploration Project" conducted by MTA achieved great success with new field discoveries and huge reserve additions in 2008 and 2009. Continuing these exploration activities would be beneficial for further discoveries of lignite-bearing basins of Turkey.

The structure of this article is as follows: Section 2 reviews the geographical and geological setting of major lignite basins of Turkey and the physical and chemical properties of Turkey's lignites are also given in this section. In Section 3, classification and historical development of reserves are thoroughly studied together with some international applications of the reserve concept. The details of exploration and development activities are the subjects of Section 4. Finally, Section 5 concludes and makes some suggestions for further studies.

2. Geological setting of lignite basins

Although bituminous coals are found mostly in the paralic Zonguldak basin of Carboniferous age in the western Black Sea coast of Turkey, lignites are distributed mostly in continental sedimentary basins of Tertiary age all over the country (Fig. 1).[1] These lignites also contain very little amounts of subbituminous coals.

The lignite basins cover an area of 110,000 km^2 of which 2% is Eocene, 6% is Oligocene, 41% is Miocene, and 51% is Pliocene in age. They are distributed in wide geographic areas, especially in Central Anatolia (558.9 km^2), Aegean (345.3 km^2), Thrace Basin (219.8 km2), and East Anatolia (184.9 km^2) in Turkey (Tuncalı et al., 2002). The lignite seams in these basins are mostly of Paleogene (Eocene and Oligocene) and Neogene (Miocene and Pliocene) age. Some small seams exist in Jurassic strata in the Gümüşhane, Bursa, and Adana regions and in Cretaceous strata in the Bursa and Artvin regions (Şengüler, 2010; Tuncalı et al., 2002; Ünalan, 2010). The maximum depths and ranges of thicknesses of lignite seams in Turkey vary significantly among different basins: 605 m and 0.35–14.90 m in Eocene basins, 332 m and 0.05–5.10 m in Oligocene basins, 828 m and 0.10–57.00 m in Miocene basins, and 426 m and 0.10–87.00 m in Pliocene basins, respectively (Tuncalı et al., 2002).

The lignite-bearing basins display the characteristics of different geological settings (A. I. Okay, 2014, pers.comm.; Görür and Okay, 1996; Şengüler, 2010; Turgut et al., 1991) but the most common basins are the grabens and half-grabens, which were formed in the Aegean Region as a consequence of the westerly escape of the Anatolian continent during Neogene (e.g., Barka et al., 1994; Ediger and Tuna, 1993). Lignite seams are mainly formed together with volcano-clastics and carbonates, which were deposited in lacustrine and fluviatile environments in those tectonically-active basins. One of the most important features of these basins is the association of organic matter deposition with volcanic activity (Ediger, 1990). However, the volcanic heat impact was

[1] Some very limited occurrences of bituminous coals also exist in addition to the Zonguldak basin in the Eastern Pontides (Mann et al., 1998) and in the Eastern Taurids (Korkmaz and Gülbay, 2007).

mild and enhanced heat flux density caused by high geothermal gradient particularly in grabens was the major cause of regional coalification process. Since such environments were essentially formed on land, lignites are mostly limnic rather than paralic. Also, the seams do not have a wide geographic extension because of the faults bounding the coal-forming environments. In addition, rate of subsidence and material influx in these basins were not balanced especially at the fault-bounded margins, resulting in the formation of numerous thin seams with clastic intercalations in-between. These geological features lower the quality of Turkish lignites as well as making the coal uneconomical to mine as it is too thin and splitted (MTA, 2010).

The following section provides some detailed information about geological aspects of four of the most important lignite basins in Turkey, namely (1) Kahramanmaraş–Afşin–Elbistan, (2) Konya–Karapınar, (3) Thrace, and (4) Manisa-Soma basins. The first three of these basins have the largest reserves and represent plains basins, basins related with epirogenic movement, and foreland basins, respectively; and the last one is also one of the largest basins, representing very typically graben and half-graben basins.

2.1. Kahramanmaraş–Afşin–Elbistan Basin

The Kahramanmaraş–Afşin–Elbistan basin, which is a typical plains basin, contains the biggest lignite reserves in Turkey. The coal-forming environments in this basin are formed within thick basement rocks, which are basically composed of Permian–Carboniferous and Upper Cretaceous limestones and Eocene ophiolites composed mainly of limestones and serpentinites. The lignite-bearing Pliocene strata are mainly composed of terrestrial deposits formed in lacustrine and fluviatile environments. Lacustrine deposits are composed of fine clastics such as claystone, marl, and siltstone together with some conglomerates at the bottom and lignite horizons together with gyttjas at the top of the sequence. The lacustrine series are terminated with fresh water limestones and on top of it fluviatile conglomerates, sandstones, and mudstones deposited during the post-Neogene period.

2.2. Konya-Karapınar Basin

The Konya-Karapınar Basin, similar to other Middle Anatolian basins around Tuzgölü and the vicinity, are basins related with epirogenic movement. The basement rocks of this basin, which are included into the Berendi Formation, are composed of medium- to thick-layered limestones and dolomitic-limestones. These rocks are covered unconformably by the Halkapınar Formation, which is composed of sandstones and siltstones with volcanic intercalations of Lower Paleocene–Middle Eocene age; Divlek Formation, which is composed of medium- to thick-layered, yellowish to cream colored, fossiliferous sandy limestone, conglomerate, and clayey limestone of Eocene–Miocene in age; and İnsuyu Formation, which is composed of clayey limestone, siltstone, sandstone, mudstone, and claystone of Upper Miocene–Pliocene in age. All of these formations are deposited in lacustrine environments. The İnsuyu Formation is later overlain conformably by the Hotamış Formation, which is composed of claystone, siltstone, sandstone, fossiliferous shales, and lignite seams deposited in lacustrine and fluviatile environments during Pliocene time. The uppermost Mekedağı Formation unconformably overlying the previous rocks is composed of volcano-sedimentary rocks and alluvial fan deposits of Quaternary age. Two major faults, extending E-W direction affect the distribution of lignite seams at the NW part of the region.

2.3. Thrace Basin

The Thrace Basin is a typical foreland basin with the third largest lignite reserves. The lowermost sedimentary unit placed on top of the Çetmi Ophiolithic Melange is the Eocene aged Gaziköy Formation, which is composed of thin-layered sandstone, siltstone, silicified tuff, and shales. This formation is overlain by the Keşan Formation, which is composed basically of sandstones; the Soğucak Formation which is composed of light-colored fossiliferous micritic a reefal limestones; gray colored shales, sandstones, and clayey limestones intercalated with tuffs of Eocene age. The Oligocene sediments start with green–gray shale, marl, and tuff of the Mezardere Formation at the bottom continue with sandstone, conglomerate, limestone, and thin lignite seams of the Osmancık formation in the middle and gray–green claystone, sandstone, conglomerate, tuff, and lignite seams of the Danişmen Formation at the top. The Miocene rocks are represented by tuffs and agglomerates of the Hisarlıdağ volcanics; claystone, siltstone, and sandstone of the Çanakkale Formation; mudstone, sandstone, and limestone of the Çekmece Formation; and conglomerate, sandstone, and siltstone of the Ergene formation. The uppermost Trakya Formation of Pliocene age is composed of loose conglomerates, sandstone, and some siltstone.

2.4. Manisa-Soma Basin

One of the typical graben basins of Turkey is the Manisa-Soma Basin, which has 666,083,000 tons of apparent and probable reserves of relatively high-quality lignites with calorific values varying from 2080 to 3340 kcal/kg. The lignite-bearing Miocene strata in this basin are deposited unconformably on the basement rocks, consisting of Paleozoic schists and graywackes and Mesozoic crystalline limestones. The Miocene-aged graben is filled syngenetically with conglomerate–sandstone–claystone intercalations with lower lignite beds at the bottom and with marl layers with abundant leaf and plant fossils and economical lignite seams at the top. The Miocene strata are unconformably covered by various volcano-clastics, consisting of sandstones, mudstones, varicolored clay, tuff, marl, andesite, basalt, agglomerate, lignite, silicified limestones, laminated claystones, and tuffites of Pliocene age. The entire series are finally covered by Pleistocene volcano-clastics and alluvium and alluvial fan deposits of Holocene. The Soma Basin is a half-graben bounded by a normal fault at the north and cropped out at the south. The Miocene lignite-forming basins are formed in older horsts and grabens bounded by normal faults extending NE-SW directions. Later during Miocene and Pliocene, new faults extending NW-SE direction formed the secondary horst and graben systems.

3. Physical and chemical properties of Turkey's lignites

Most of Turkey's lignites have low calorific value but high contents of volatile matter, moisture, ash, and sulfur. The chemical properties change in a wide range, for instance, the calorific values vary from 1185 kcal/kg to 5574 kcal/kg (Table 1). According to Şengüler (2010) almost 75% of lignites have calorific values below 2500 kcal/kg, 17% between 2500 and 3000 kcal/kg, and only 8% over 3000 kcal/kg. Moreover, Ünalan (2010), based on 8374 billion tons of reserves, calculated that 56% of lignites have calorific values between 1000 and 1500 kcal/kg, 12% between 1500 and 2000 kcal/kg, 23.5% between 2000 and 3000 kcal/kg, 5.1% between 3000 and 4000 kcal/kg, and 3.4% more than 4000 kcal/kg. In other words, 68% of the reserves are lower than 2000 kcal/kg calorific values and most of these reserves are found in the Afşin–Elbistan basin, which contains 3357 million tons of lignites with an average calorific value of 1050 kcal/kg.

Table 1
Generalized chemical properties of Turkish lignites (Şengüler, 2010).

Chemical property	Minimum	Maximum
Fixed carbon	8.86%	44.14%
Volatile matter	8.93%	43.84%
Moisture	1.20%	57.66%
Ash	5.21%	59.09%
Calorific value	1185 kcal/kg	5574 kcal/kg
Total sulfur	0.21%	10.66%

The most comprehensive data on the chemical, mineralogical, and petrographical properties of lignite seams were compiled by Tuncalı et al. (2002), who analyzed samples taken from 187 basins. Having performed proximate and ultimate analyses they found that the moisture, ash, volatile matter, fixed carbon and sulfur contents of Turkish lignites range between 1.2 and 57.7%, 5.2–56.1%, 18.3–43.8%, 8.9–44.1%, and 0.2–10.7%, respectively and that the calorific values range between 1185 and 5574 kcal/kg. Furthermore, the ultimate analysis revealed that elemental carbon ranges between 14.3 and 61.4%, hydrogen between 1.3 and 4.3%, nitrogen between 0.2 and 3.3%, and oxygen between 0.8 and 23.2%. On the other hand, the most commonly observed macerals are found to be huminite (31–90%), liptinite (2–10%), and inertinite (1–18%). The most common minerals are oxides (quartz and opal), clays (kaolinite and simectite), silikates (mica, chlorite, zeolite), carbonates (calcite, siderite, dolomite), sulfur (pyrite) and sulfates (gypsum).

Proximate analyses results of 30 major lignite fields of TKİ are given in Table 2. According to the figures, the average volatile matter, moisture, ash, and sulfur contents are 25.52%, 28.96%, 27.36%, and 2.23%, respectively. The ranges are 5–39% for volatile matter, 6–50% for moisture, 11–43% for ash, and 0.6–4.5% for sulfur. On the other hand, the average and range of calorific values are 2501.16 kcal/kg and 1110–5330 kcal/kg, respectively.

In summary, Turkish lignites are mainly found in some small basins, which are usually tectonically isolated from each other. The lignite-bearing strata formed in such basins are characterized by numerous thin seams that are separated by intercalations and that show low rank of coalification. In addition, they have high moisture, ash, and sulfur contents. These geological and chemical characteristics of Turkish lignites make them unfavorable for consumption. However, since they are the most valuable energy source of the country they should benefit the economy in the most efficient and environment-friendly way provided that additional lignite production is economically feasible.

4. Classification and historical development of reserves

There exists no scientifically developed reserve classification system used for Turkish lignites. Although reserve definitions were standardized by the Turkish Standards Institute (TSI) with the Code TS 5959 in 1988 (TSI, 1988), only a few studies have used it until now. Having studied the lignite reserves in Turkey, Yüksek et al. (2001) correctly noted that reserves are calculated differently by engineers, academicians, and politicians and this causes considerable misunderstanding.

The most commonly used classification scheme for Turkey's coal reserves includes “apparent”, “probable”, and “possible” categories. In addition to this basic classification, categories such as “ready” and “geological” are also used in some cases. Although not defined clearly, these three basic classes correspond in most cases to “measured”, “indicated”, and “inferred”, to “proved”, “probable”, and “possible” or to simply A, B, and C categories of internationally accepted classification systems (e.g. Milici et al., 2013). However, the probability requirements, similar to the ones used for petroleum resources under SPE/WPC of >90%, 70–90%, and <70% for these internationally accepted three categories (Demirmen, 2007) are not being considered in most Turkish coal applications.

TKİ geologists define the “apparent” class as the reserve calculated in three dimensions by using reliable data obtained from geological control points such as outcrops, wells, trenches, galleries, etc. Since the area is geologically and geophysically well-known, seams are reasonably expected to continue throughout the area without any interruptions. In this category error limits are taken as ±20%. In “probable” reserves, only two dimensions are known well because geological check points are present but widely distributed. On the other hand, in “possible” reserves none of the dimensions are known because of insufficient exploration. In this category confidence intervals are taken to be more than ±50%. In many studies, the boundaries of the resource and reserve classes are even vaguer, causing serious problems in economic

Table 2
Chemical properties of lignite fields of TKİ, 2010 (MTA, 2010).

Field	Volatile matter (%)	Moisture (%)	Ash (%)	Sulfur (%)	Calorific value (kcal/kg)
Manisa-Soma–Eynez	27	13	33	1.3	3150
Manisa-Soma–Deniş	20	18	40	1.2	2080
Manisa-Soma	26	15	36	1.2	2940
Çanakkale-Çan	30	23	25	4.2	3000
Kütahya-Tunçbilek	25	15	41	1.6	2560
Konya-Ilgın	26	50	11	1.1	2180
Konya-Beyşehir	17	48	25	1.1	1110
Adana-Tufanbeyli	24	41	28	2.1	1298
Muğla–Yatağan–Eskihisar	27	34	27	3	2185
Muğla–Yatağan–Tınaz	25	33	27	2.41	2111
Muğla–Yatağan–Bağyaka	25	38	26	1.26	1807
Muğla–Yatağan–Bayır	31	26	24	2.8	2670
Muğla–Yatağan–Turgut	–	27	27	3.1	2635
Muğla–Yatağan–Taşkesik	–	30	24	–	2660
Muğla–Milas–Sekköy	–	34	26	1.2	1861
Muğla–Milas–Yeniköy	–	30	29	–	2180
Muğla–Milas–Hüsamlar	28	32	29	1.2	1775
Muğla–Milas–Belentepe	–	30	31	1.3	1864
Muğla–Milas–Karacahisar	–	30	22	4.5	2279
Muğla–Milas–Alatepe	5	27	15	4.3	4200
Kütahya-Seyitömer	22	32	43	1.2	2080
Bursa-Orhaneli	34	24	24	2	2500
Bursa-Keles-Harmanalanı	26	34	26	1.5	1900
Bursa-Keles-Davutlar	–	31	26	4.5	2340
Şırnak-Silopi (Asfaltit)	30	6	31	4	5310
Şırnak (Asfaltit)	39	6	31	4.5	5330
Bolu-Göynük	25	27	31	1.8	2340
Tekirdağ-Saray	20	45	16	1.9	2080
Çorum-Dodurga	39	23	23	1.6	3150
Bingöl-Karlıova	16	47	24	0.6	1460

Table 3
Turkey's lignite reserves according to TKİ (1973). Numbers are in thousand tons.

Name of the field	Corresponding ınstitution	Reserves				
		Apparent	Probable	Possible	Geologic	Total
Ankara-Beypazarı	TKİ	100,000	38,000	5000	900,000	1,043,000
Erzurum-Aşkale	TKİ	60,200	164,600	2,255,000		2,479,800
Maraş-Elbistan	MTA	1,770,000		1,376,000		3,146,000
Total of 65 Fields		2,648,567	570,014	4,108,775	1,010,200	8,337,556

and technical feasibility studies (Köktürk and Narin, 1994). In general, reserve classifications and calculations based on recoverability and salability, which are extremely important for economic feasibility, are not sufficiently accredited in Turkey.

The history of Turkish lignite reserve estimation started about a century ago. One of the first records on Turkish lignite reserves is the documents of the 13th International Geology Congress held in 1913 (Dominian, 1915). It was estimated in these documents that the coal reserves of Zonguldak Basin were 4–5 billion tons but they revealed no information about lignite reserves. The oldest record about lignite reserves in Turkish literature was the report published in 1940 with the title of *Energy Economics of Turkey*, in which the possible and probable reserves are given as 1.13 billion tons and 143.3 million tons, respectively (EIE, 1940). According to this report, 91% of probable reserves are found only in three basins, namely Seyitömer (65 million tons), Ağaçlı (50 million tons), and Soma (15 million tons). Later MTA (1945) estimated Turkey's lignite reserves as 201 million tons of which 85% is found in seven basins, namely Seyitömer–Aydan (90 million tons), Tavşanlı (40 million tons), Soma (26 million tons), Ağaçlı (7 million tons), Balkaya (3 million tons), Değirmisaz (3 million tons), and Çeltek (1 million tons), and the remaining 15% is found in different regions such as Balıkesir, Bursa, Bilecik, Denizli, Aydın, İzmir, and Ankara.

After the establishment of TKİ in 1957, some scientifically and technically defined reserve classifications such as "proven" and "salable" began to be used in lignite reserve estimations. In 1959, for instance, 95.02 million tons of lignite in various categories were discovered by MTA and transferred to TKİ (MTA, 1959). These newly found lignite reserves were classified as "proven" (Seyitömer-Kütahya 50 million tons), "salable" (Tunçbilek-Kütahya 39 million tons and Değirmisaz-Kütahya 2,5 million tons), and "reserve" (Çeltek-Amasya 2,2 million tons, Balkaya-Erzurum 1,1 million tons, and Kükürtlü-Erzurum 22 thousand tons). In addition, the reserves in 22 new fields were estimated to be 230.68 million tons. However, confusions in lignite reserve calculations continued in the 1960's. For instance, *General Energy Report of 1968* estimated the lignite reserves as 3 billion tons whereas *First Five Years Plan (1963–1967)* as only 847,000 tons (Ulutan, 1987).

The relatively well-defined reserve classifications began to be used in the 1970's. TKİ (1973) estimated Turkey's lignite reserves as 8.337 billion tons of which 4.108 billion tons are "possible", 0.57 billion tons are "probable", and 2.648 billion tons are "apparent". Although the definitions of these classes were not clear, geological information was first used in reserve estimations of 65 lignite fields in Turkey. Three of these lignite fields, namely Maraş-Elbistan (3.146 billion tons), Erzurum-Aşkale (2.479 billion tons), and Ankara-Beypazarı (1.043 billion tons) constituted 80% of total reserves (Table 3). Köktürk and Narin (1994) have noted that "possible" reserves increased from 44 million tons in 1965 to 3.7 billion tons in 1970, 4.1 billion tons in 1975 and 6.0 billion tons in 1978.

The year 1986 was an important milestone for lignite reserve classification. In this year MTA formed a special commission, whose main responsibility was to compile all the historical reserve estimations and evaluate Turkey's lignite endowment. The first comprehensive lignite inventory was built up with those efforts (MTA, 1986). In this study, Turkey's total lignite resources were given as 8,209,838,000 tons of which 7,910,462,000 tons were defined as reserve and the reserves are further classified as "possible" (126,708,000 tons), "probable" (1,872,997,000 tons), and "apparent" (5,910,757,000 tons). The reserve estimation of MTA in 1986 and that of TKİ in 1973 differ significantly. MTA estimated a 5% increase in total reserves whereas a 45% increase in apparent reserves from 1973 to 1986.

The development of lignite reserves after 1986 can as well be examined in the World Energy Council Turkish National Committee's (WEC TNC) reports entitled *Energy Statistics* although data are missing in some categories (WEC TNC, 1986, 1990, 1994, 1997, 2002, 2006). As shown in Table 4, the total reserves, which were around 8 billion tons from 1986 to 2002, have dramatically increased to 11.443 billion tons in 2008. Also, "producible or recoverable reserves", which can be accepted to be equivalent to modern "proved reserves", are 55% (1989) and 48% (1993 and 1996) of total reserves and 61% (1989) and 53% (1993 and 1996) of apparent reserves. The apparent reserve estimates in WEC TNC (2006) included seams which have a maximum depth of 800 m and a maximum thickness of 0.8 m.

Most recently, the second *Lignite Inventory of Turkey* estimated a total reserve of 11.571 billion tons of lignite (MTA, 2010) and *Sectoral Report of Lignite* estimated 11.44 billion tons (TKİ, 2011, 2012). Around 86% of this amount is owned by public institutions such as EÜAŞ (42%), MTA (22%), and TKİ (21%) whereas the share of the private sector is only 14%. The latest figures of lignite reserve estimates are given by TKİ (2012). As shown in Table 5, by the end of 2010 Turkey had 11.751 billion tons of lignite reserves of which 10.782 billion tons are apparent, 826 million tons are probable, and 143 million tons are possible reserves. Moreover, 86.4% of total reserves are owned by public institutions, namely EÜAŞ (41.2%), MTA (23.4%), and TKİ (21.8%) and the remaining 13.6% are owned by the private sector.

MTA (2010) provides distribution of TKİ's lignite reserves in its enterprises and fields in 2011 (Table 6). 79.3% of TKİ's total reserves are distributed among its four enterprises, ELİ, GLİ, GELİ and SLİ. The remaining 20.7% are distributed among independent fields and some other operational bodies of TKİ. Out of the enterprises ELİ has the largest reserves (702.7 million tons), followed by GLİ (700.7 million tons), GELİ (419.9 million tons) and SLİ (277.4 million tons). Apparent reserves constitute 94.1% and 88.4% of lignite reserves of enterprises total and TKİ's total, respectively. There exist six fields, which have more than 100 million tons of lignite reserves, within the enterprises: Manisa-Soma–Eynez of ELİ, Adana-Tufanbeyli of GLİ, Kütayha-Tunçbilek of GLİ, Muğla-Milas–Yeniköy of GELİ, Manisa-Soma–Deniş of ELİ and Kütahya-Seyitömer of SLİ.

Table 4
Lignite reserves in WEC-TNC reports (WEC-TNC, 1986, 1990, 1994, 1997, 2002, 2006). Numbers are in thousand tons.

WEC TNC	Reserves					Resource
	Producible	Apparent	Probable	Possible	Total	
1986	–	–	–	–	7,843,652	8,143,028
1989	4,239,000	6,946,000	689,000	114,000	7,750,349	8,049,725
1993	3,907,000	7,339,000	625,000	110,000	8,074,996	8,374,372
1996	3,907,000	7,339,000	625,000	110,000	8,074,996	8,374,372
1997	–	7,330,000	625,000	110,000	8,074,996	8,374,372
2002	–	7,330,000	625,000	110,000	8,074,996	8,374,372
2008	–	9,837,000	1,344,000	262,000	11,443,000	–

Table 5
Turkey's lignite reserves by the end of 2010 (TKİ, 2011). Numbers are in thousand tons.

Institution	Apparent	%	Probable	%	Possible	%	Total	%
EÜAŞ	4,741,300	44.0	104,500	12.6	–	–	4,845,800	41.2
MTA	2,643,196	24.5	108,334	13.1	2964	2.1	2,754,494	23.4
TKİ	2,303,394	21.4	251,811	30.5	1560	1.1	2,556,765	21.8
Public total	9,687,890	89.9	464,645	56.2	4524	3.2	10,157,059	86.4
Private sector	1,094,189	10.1	362,122	43.8	138,617	96.8	1,594,927	13.6
Total	10,782,079		826,767		143,141		11,751,987	

Because of the reasons discussed above there are significant discrepancies between numbers of reserve estimations of Turkish lignites between Turkish and international publications. For instance, according to BP's *Statistical Review of World Energy*, which uses "proved reserves" defined as "generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known deposits under existing economic and operating conditions", Turkey has 2343 million tons of coal reserves of which 529 million tons are anthracite and bituminous coals and 1814 million tons are subbituminous and lignites (BP, 2013). Turkey ranks 17th in the world with a share of 0.3% in total and the R/P ratio are 33 years. On the other hand, the most recent estimates of MTA and TKİ are 1.31 billion tons of hard coal and 12.6 billion tons of lignite reserves (MTA, 2010; TKİ, 2012; TTK, 2011). Moreover, TKİ (2012), by using estimates of MTA (2010), suggests that the share of Turkey in world's total lignite reserves is 5.9%. It is also arguable whether this much lignite reserves can be considered as "abundant" or not (e. g., Eskikaya, 1989).

5. Exploration and development

Geological and geophysical exploration activities in Turkey have been mainly carried out by MTA although other institutions such as TKİ, Electrical Power Resources Survey and Development Administration (EIE, hereafter) and State Hydraulic Works (DSI, hereafter) also contributed to the drilling activities.

As a result of the extensive exploration activities carried out in an area covering 41,320 km^2 out of 110,000 km^2 area of continental Tertiary basins, MTA discovered lignite occurrence in a 1474 km^2 area (Köktürk and Narin, 1994; Tuncalı et al., 2002). Geological and geophysical exploration is historically concentrated in this area. According to MTA Archives, lignite exploration activities were carried out by some Turkish and European geologists between 1923 and 1935 in provinces such as Tekirdağ, Ankara, Amasya, Kütahya, and Erzurum (Şengüler, 2010, pers. comm.). Later, after its establishment in 1935, MTA became the sole authority for exploration of minerals including coal. The first lignite fields which were explored by MTA were Soma (Manisa) and Seyitömer (Kütahya) fields. Extensive geological mapping was carried out in the Manisa-Soma–Tarhala field between 1935 and 1941. Additionally, the Kütahya-Seyitömer field was explored by drilling with 64 boreholes in 1936 (MTA, 2010).

Exploratory drilling was mainly carried out by MTA although a few wells were drilled by TKİ until the end of 1960. The discovery of Afşin–Elbistan lignites in 1967 was an important milestone for the development of relatively lower quality coals. MTA's drilling totaled 8351 m in 1965, 7686 m in 1966, 40,000 m in 1967, 54,000 m in 1968,

Table 6
TKİ's lignite reserves by fields and enterprises, 2011 (MTA, 2010). Numbers are in thousand tons.

Enterprises	Fields	Reserves			
		Probable	Apparent	Ready	Total
ELİ (Aegean Lignite Enterprises)	Manisa-Soma–Eynez	39	360,996	1263	401,259
	Manisa-Soma–Deniş	11	160,194	2661	173,855
	Manisa-Soma	13	43,984	3281	48,565
	Çanakkale-Çan		78,823	250	79,073
	Total of ELİ	513	643,997	7455	702,752
GLİ (Western Lignite Enterprises)	Kütahya-Tunçbilek		272,408	4187	276,595
	Konya-Ilgın	974	1853	267	19,771
	Konya-Beyşehir		81,011		81,011
	Adana-Tufanbeyli		323,329		323,329
	Total of GLİ	974	695,278	4454	700,706
GELİ (Southern Aegean Lignite Enterprises	Muğla–Yatağan–Eskihisar		36,646		36,646
	Muğla–Yatağan–Tınaz		22,695		22,695
	Muğla–Yatağan–Bağyaka		2601		2601
	Muğla–Yatağan–Bayır		23,788		23,788
	Muğla–Yatağan–Turgut		2876		2876
	Muğla–Yatağan–Taşkesik		37,995		37,995
	Muğla–Milas–Sekköy		18,802	250	19,052
	Muğla–Milas–Yeniköy		16,204	215	162,255
	Muğla–Milas–Hüsamlar		53,552	3106	56,658
	Muğla–Milas–Belentepe		1075	1551	12,301
	Muğla–Milas–Karacahisar		45		45
	Muğla–Milas–Alatepe		12,733		12,733
	Total of GELİ		414,862	5122	419,984
SLİ (Seyitömer Lignite Enterprises)	Kütahya-Seyitömer	328	147,419	314	180,533
	Bursa-Orhaneli		31,371	238	31,609
	Bursa-Keles-Harmanalanı		26,198	69	26,267
	Bursa-Keles-Davutlar	19,945	17,557		39,062
	Total of SLİ	52,745	222,545	621	277,471
Enterprises total		105,019	1,976,682	17,652	2,100,913
Others total		176,186	364,537	0	547,302
TKİ total		281,205	2,341,219	17,652	2,648,215

Table 7
Summary of exploration wells drilled between 1970 and 2002 (Tuncalı et al., 2002).

Explanation	Value
Total bore hole depth	1,225,648.66 m
Total number of boreholes	7863
Number of boreholes penetrating lignites	6243
Range of borehole spacing	50–2650 m
Range of coal seam thickness	0.05–87 m
Range of coal seam depth	150–828 m

and 86,000 m in 1969, resulting in significant reserve increases from 444 million tons to 3.7 billion tons over 5 years (Köktürk and Narin, 1994).

However, the existing data set on lignite drilling activities in this period is highly inconsistent. According to Tuncalı et al. (2002), total depth of boreholes drilled by MTA was 401,720 m in 1970s, 437,817 m in 1980s, 352,446 m in the 1990s. According to Altaş (1993), TKİ drilled 636,300 m between 1970 and 1986 in order to discover new reserves to meet the demand of Afşin–Elbistan power plant with an installed capacity of 340 MW.

According to data presented by Tuncalı et al. (2002), 7863 wells were drilled with a total length of about 1225 km from 1970 to 2002 (Table 7). Most of these exploration activities with drilling were carried out in the Aegean Region with 2841 wells and 494,609.1 m total length. A total of 2358 wells constituting 83% of the total penetrated lignite seams. The second and third most densely explored regions are the East Anatolian and Central Anatolian Regions, respectively. In the East Anatolian Region a total of 1414 wells were drilled with a total length of 225,781.4 m. A total of 1271 (90%) of these wells penetrated lignite seams. In the Central Anatolian Region a total of 1409 wells were drilled with a total length of 173,765.9 m. A total of 1040 (74%) of these wells penetrated lignite seams. In general, it was noted that a total 6243 wells out of 7863 wells drilled between 1970 and 2002 penetrated lignite with a success ratio of 80%. On the other hand, according to Şengüler (2010), a total of 9800 wells were drilled until 2010 for lignite exploration in Turkey and 8000 of them penetrated lignite with a ratio of 89%. According to MTA (2010) a total of 204.54 million tons of lignite reserves were found in 9 different basins due to these exploratory efforts during the period between 1970 and 1979.

Exploratory wells drilled in the TKİ lignite fields after 1980 are, however, well documented (Fig. 2). During 31 years between 1980 and 2010, cumulative drilling depth was 863,076.89 m of which 54.6% was by TKİ, 26.7% by MTA, 11.1% by EIE, and only 3.9% by DSI.

The curve of annually drilled meters (Fig. 2) in this period represents two well-defined troughs in 1982 and 2003 and some peaks in between them. The curve first declines to 21,338.65 m in 1982 from 51,211.5 m in 1980 and then increases to its first double peaks at 1987 (69,739.06 m) and 1989 (66,060.65 m) before it declines down to 7459.75 m in 2003. It then increases to 52,932 m in 2009 before it declines to 30,346 m in 2010. This last peak is primarily formed as a result of increased drilling activities of the Lignite Exploration Project conducted by MTA. By 2011 TKİ was holding 145 exploration licenses all over Turkey (MTA, 2010). If the corporation decides to evaluate these licenses in the near future, the total drilling activities, which declined in 2010, would increase again.

Fig. 2 clearly shows that the total curve is primarily shaped by the other institutions' curve since the TKİ curve represents a relatively stable trend, forming only one small peak in 1986 with a value of 31,232.20 m. Both curves cut each other six times between 1980–1981, 1986–1987, 1987–1988, 1988–1989, 1989–1990, and finally 2005–2006. Consequently, TKİ's total drilling depths were bigger than other institutions during the periods between 1980–1981 and 1986–1987 and 1989–1990 and 2005–2006. These periods represent TKİ's dominance in lignite exploration activities in Turkey.

The major reason for the decrease of drilling activities of TKİ and other institutions after 1985 and 1986 is directly related with Mining Law 3213 dated 1985. With this law MTA's lignite exploration activities were limited with its license areas, which constituted only 4% of lignite licenses. This decision affected not only the drilling activities but also discoveries (Köktürk and Narin, 1994).

The TKİ data set also reveals the 30-year-cumulative depth of wells drilled in its enterprises from 1980 to 2010. According to Table 8, the most extensive drilling activities were carried out in GLİ, ELİ, and GELİ with shares of 41.97%, 16.47%, and 10.75%, respectively. However, TKİ was responsible for most of the drilling in GLİ (76%) whereas the major institutions were MTA in ELİ (44%) and EIE in GELİ (36%). On the other hand, TKİ was the only institution which performed drilling in OAL (13,046.33 m) and AEL (7307.15 m); and drilling activities in SKLİ (5609.75 m) and GAL (3765.60 m) were carried out solely by MTA. During the mentioned period the majority of drilling was done by MTA in enterprises ELİ, ADL, ILİ, DLİ, SKLİ, and GAL, while by EIE in enterprises GELİ, ÇLİ, and MLİ.

The intensity of drilling activities correlates well with new field discoveries (Fig. 3). According to data presented in the latest *Lignite Inventory of Turkey*, the number of lignite field discoveries was 43 in 1980's, 4 in 1990's, and 60 in 2000's (MTA, 2010). The most successful years were 2009 (36 fields), 2008 (23 fields), 1986 (13 fields), 1988 (8 fields), and 1983 (8 fields). These dates correspond with the peaks in drilling meters. On the other hand, no discovery was made in years 1977, 1988, 1992, 1994–2002, and 2004–2007, when the exploratory drilling activities were minimum because of increasing natural gas usage and economic crises in the public sector.

There also exists a close relationship between the amount of reserve additions and exploratory drilling activities according to MTA's (2010) data (Fig. 4). During the first drilling peak between

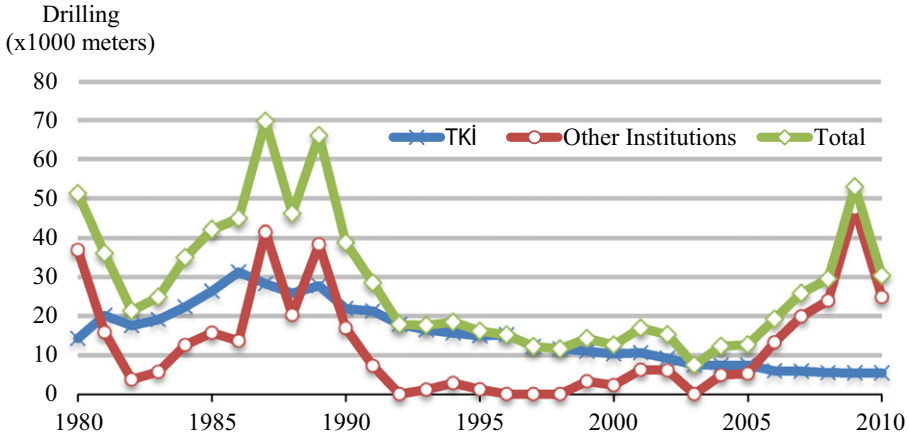

Fig. 2. Drilling activities, 1980–2010.

Table 8
Drilling activities performed in enterprises of TKİ, 1980–2010.

Name of the enterprise	Institution holding drilling activity					
	TKİ	MTA	EIE	DSI	Private	Total
GLİ	276,446.50	71,378.19	7880.50		6518.00	362,223.19
ELİ	62,342.95	64,355.65		15,410.00		142,108.60
GELİ	28,126.35	29,736.60	33,706.80		1219.80	92,789.55
ÇLİ	147.00	17,860.75	38,687.95	250.00		56,945.70
SLİ (Seyitömer)	41,937.00		4915.30			46,852.30
TLİ	403.80	4524.00		6913.50	23,962.00	35,803.30
ADL	11,693.63	14,293.45		4081.50		30,068.58
ILİ (Ilgın-Ermenek)	5336.45	13,090.28	5242.00	487.00		24,155.73
Göynük	15,718.25			3481.00		19,199.25
OAL	13,046.33					13,046.33
DLİ	3940.00	5750.50		2640.00		12,330.50
MLİ	5416.90		5723.70			11,140.60
AEL (Afşin Elbistan)	7037.15					7037.15
SKLİ (Sivas-Kangal)		5609.75				5609.75
GAL		3765.60				3765.60
Total	471,592.31	230,364.77	96,156.25	33,263.00	31,699.80	863,076.13

1982 and 1992 in the figure, a total of 1.207 billion tons of reserves were added. The biggest additions were in 1983 (449.554 million tons), 1986 (340.747 million tons), and 1988 (270.727 million tons). From 1990 till 2008 there wasn't any significant change in total reserves and the drilling activities declined by more than 80% until 2003. Drilling activities and reserve additions also represent high correlation over the last years. Reserves increased by more than 300% from 2007 to 2008 and a further 65.6% from 2008 and 2009, when drilling activities reached a 30 year peak value of 52.9 km. This significant escalation in exploration activities and hence discoveries, was driven primarily by Lignite Exploration Project started in 2005.

6. Conclusions and remarks

As a result of reviewing all available data on geology, reserves, and exploration of lignites of Turkey, this article concludes that production of Turkish lignite reserves can and should be increased for their indisputable contribution to the country's economy in spite of geological, geochemical, petrographical, and mining problems of the reserves. The problems associated with lignite production and consumption in Turkey are quite severe, yet relieving the burden of energy import dependency on country's economy is also vitally important, therefore, new policies should be developed in a way that they should benefit the economy in the most efficient and environment-friendly way.

In Turkey, both lignite production and share of domestic lignite in primary energy consumption increased steadily from 43.709 million tons (10.4%) in 2004 to 72.550 million tons (14.0%) in 2011. However, reserve increases recorded especially during the last years are sufficient enough for further production increases at higher rates. Even if the "apparent reserves" given by TKİ (2012) are considered, the lignite reserves will last close to 150 years if the rate of production in 2012 is kept constant.

Lignites are the most valuable energy resource of the country, which suffers deeply from dependency on foreign energy sources, and they should be utilized, needless to say, in an environment-friendly way, i.e., by taking care of all concerns about environmental degradation whether local or global. Newly developed CCT (Clean Coal Technology) will provide good opportunities for such a responsible production and use of lignites. The authors of this study will feel comfortable if this study is used in this line.

However, although the lignite resources of Turkey are considered to be abundant, reserve definitions used in the country are highly controversial. There does not exist any scientifically developed reserve classification system. "Apparent", "probable", and "possible" categories are the most commonly used classification scheme for Turkey's coal reserves. These categories correspond possibly to "measured", "indicated", and "inferred", or to a lesser extend to "proved", "probable", and "possible" categories of internationally accepted classification systems. Yet, the major problem is that the probability requirements for the international classifications are not being used in Turkish applications. Therefore, exploration activities should be concentrated on reserve classifications not discovery of new reserves. Reserve estimation practices in the country should definitely be revised and the impractical reserve classification system should be replaced by modern ones, including the producible amounts that are technically and economically feasible. Revision of reserves will provide a

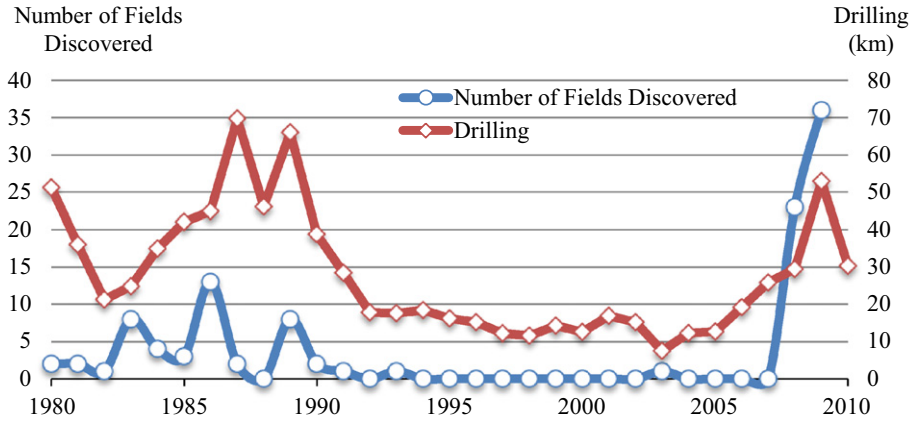

Fig. 3. Field discoveries vs. drilling activities, 1980–2009.

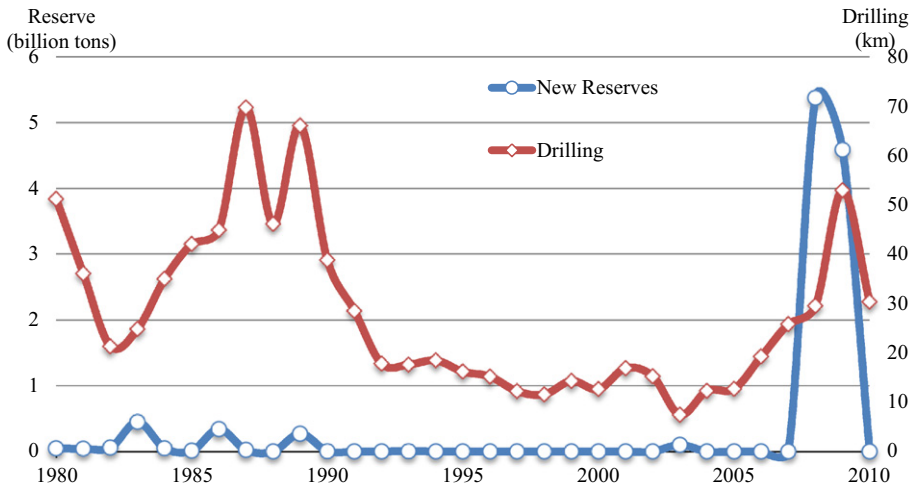

Fig. 4. Reserve development vs. drilling activities, 1980–2009.

more realistic evaluation of the country's lignite potential for developing medium and long-term energy strategies and policies for decision- and policy-makers.

MTA has been the most important institution in lignite exploration and development activities for the last 50 years. The institution increased its exploration efforts over the last years, especially with the Lignite Exploration Project initiated in 2005. These efforts produced significant successes and reflected huge reserve additions. The massive costs and risks associated with exploration prevent the private sector from investing in these activities. Thus MTA, as a unique and privileged governmental institution responsible for exploration of precious metals and mining stocks in Turkey, must be subsidized to increase such activities to sustain long-term reserve growth in the Turkish lignite industry.

Acknowledgments

This study presents some of the results of a project entitled “History of Turkish Coal Enterprises (TKİ) and Turkish Hard Coal Enterprises (TTK), and Turkish Coal Strategies” which was carried out with the financial support provided by the Turkish Coal Enterprises (TKİ). The project was initiated at Izmir University of Economics (İEÜ), and continued at Kadir Has University (KHAS) where it was finalized. The authors are highly indebted to the management of TKİ, İEÜ and KHAS for their guidance and constant supervision as well as for providing necessary information and also for their support in completing the project. The authors would also like to thank Mücella Ersoy, TKİ for her helpful comments and Mr. Teoman Türeli, Kadir Has University Writing Center for critically editing the manuscript. Finally, we thank Ralf Littke, Editor of International Journal of Coal Geology, Reviewer #1 (Thomas Thielemann, Cologne, Germany), and Anonymous Reviewer #2 for the careful reading of our manuscript and the constructive comments.

References

Altaş, B., 1993. Enerji ve Tabii Kaynaklar Bakanlığının Kömür Politikaları (Coal Policies of the Ministry of Energy and Natural Resources of Turkey). Kömür Teknolojisi ve Kullanımı Sempozyumu. Yurt Madenciliğini Geliştirme Vakfı, İstanbul.

Barka, A.A., Sakınç, M., Görür, N., Yılmaz, Y., Şengör, A.M.C., Ediger, V.Ş., 1994. Is Aegean extension a consequence of the westerly escape of Turkey? American Geophysical Union (ASU) Spring Meeting, Baltimore, U.S.A. Abstracts, 75(16), pp. 116–117.

BP, 2013. Statistical Review of World Energy. Available at: http://www.bp.com/content/dam/bp/excel/StatisticalReview/statistical_review_of_world_energy_2013_workbook.xlsx (Access date: 23.10.2013).

Demirmen, F., 2007. Reserves estimation: the challenge for the industry. J. Pet. Technol. 2007, 80–89 (May).

Dominian, L., 1915. The coal resources of the world: a summary. Bull. Am. Geogr. Soc. 47 (10).

Ediger, V.Ş., 1990. Paleopalynology of coal-bearing Miocene sedimentary rocks associated with volcanics of the Biga Peninsula (NW Turkey) and the effect of volcanism on vegetation. N. Jb. Geol. Paläont. (Abh.) 180 (2), 259–277.

Ediger, V.Ş., 2014. Türkiye Kömür Stratejileri (Coal Strategies of Turkey). TKİ Publications, Ankara p. 497 s.

Ediger, V.Ş., Tuna, D., 1993. Primary energy resources of Turkey: hydrocarbon and coal. Chishitsu News 467, 50–58 (In Japanese).

EIE (Electrical Power Resources Survey and Development Administration), 1940. Türkiye'nin Energi Ekonomisi (Energy Economics of Turkey). EIE Publications, Ankara.

Eskikaya, T., 1989. A New National Energy Source. International Mining (December).

Görür, N., Okay, A.I., 1996. A fore-arc origin for the Thrace Basin. Geol. Rundsch. 85, 662–668.

Köktürk, A., Narin, R., 1994. Linyit Rezervleri, Kullanma İmkanları ve Arama Politikalar (Lignite Reserves, Consumption, and Exploration Policies). 2000'li Yıllara Doğru Linyit Sektörümüz Sempozyumu, November 14–15, 1994, Ankara.

Korkmaz, S., Gülbay, R.K., 2007. Organic geochemical characteristics and depositional environments of the Jurassic coals in the eastern Taurus of Southern Turkey. Int. J. Coal Geol. 70 (4), 292–304.

Mann, U., Korkmaz, S., Boreham, C.J., Hertle, M., Radke, M., Wilkes, H., 1998. Regional geology, depositional environment and maturity of organic matter of Early to Middle Jurassic coals, coaly shales, shales and claystones from the Eastern Pontides, NE Turkey. Int. J. Coal Geol. 37 (3–4), 257–286.

Milici, R.C., Flores, R.M., Stricker, G.D., 2013. Coal resources, reserves and peak coal production in the United States. Int. J. Coal Geol. 113, 109–115.

MTA (General Directorate of Mineral Research and Exploration), 1945. Bull. Miner. Res. Explor. Inst. 2 (34), 261–262.

MTA (General Directorate of Mineral Research and Exploration), 1959. The Mineral Research and Exploration Institute of Turkey, 1935–1959. MTA Publications, Ankara.

MTA (General Directorate of Mineral Research and Exploration), 1986. Türkiye Linyit Envanteri (1986 Lignite Inventory of Turkey). MTA Publications, Ankara (No. 196).

MTA (General Directorate of Mineral Research and Exploration), 1993. Türkiye Linyit Envanteri (1993 Lignite Inventory of Turkey). MTA Publications, Ankara.

MTA (General Directorate of Mineral Research and Exploration), 2010. Türkiye Linyit Envanteri (2010 Lignite Inventory of Turkey). Inventory Series No. 202MTA Publications, Ankara.

Şengüler, İ., 2010. Lignite explorations in Turkey: new projects and new reserves. 27th Annual International Pittsburgh Coal Conference, October 2010, İstanbul, Turkey.

TCME (Turkish Chamber of Mining Engineers), 1994. 2000'li Yıllara Doğru Linyit Sektörümüz Sempozyumu (Symposium on Lignite Sector Towards 2000s). Proceedings, 15–15 November 1994, Ankara.

TKİ (General Directorate of Turkish Coal Enterprises), 1973. Cumhuriyetin 50. Yılında TKİ (TKİ in the 50th Anniversary of Republic). TKİ Publications, Ankara.

TKİ (General Directorate of Turkish Coal Enterprises), 2011. 2010 Linyit Sektörü Raporu (2010 Sectoral Report of Turkey). TKİ Publications, Ankara.

TKİ (General Directorate of Turkish Coal Enterprises), 2012. 2011 Linyit Sektörü Raporu (2011 Sectoral Report of Lignite). TKİ Publications, Ankara.

TSI (Turkish Standards Institute), 1988. Maden Yataklarının Rezerv Miktarı ve Tenör Değerlerini Hesaplama Metotları (Reserves and Percentage Calculation Methods of Ore Deposits). TSI Publications, Ankara.

TTK (Turkish Hardcoal Company), 2011. 2010 Taşkömürü Sektör Raporu (2010 Sectoral Report of Hardcoal). TTK Publications, Ankara.

Tuncalı, E., Çiftçi, B., Yavuz, N., Toprak, S., Köker, A., Gencer, Z., Ayçık, H., Şahin, 2002. Türkiye Tersiyer Kömürlerinin Kimyasal ve Teknolojik Özellikleri (Chemical and Technological Properties of Tertiary Lignites of Turkey). MTA Publications, Ankara.

Turgut, S., Türkaslan, M., Perinçek, D., 1991. Evolution of the Thrace sedimentary basin in hydrocarbon prospectivity. In: Spencer, A.M. (Ed.), Generation, accumulation, and production of Europe's hydrocarbons. Special Publication of European Association of Petroleum Geoscientists. Oxford University Press, pp. 415–437.

Ulutan, B., 1987. Etibank: 1935–1985. Etibank Publications, Ankara.
Ünalan, G., 2010. Kömür Jeolojisi (Coal Geology). MTA Publications, Ankara (No. 41).
WEC-TNC (World Energy Council, Turkish National Committee), 1986. Enerji İstatistikler (1986 Energy Statistics). Proceedings of 4th Energy Congress of Turkey, Izmir.
WEC-TNC (World Energy Council, Turkish National Committee), 1990. Enerji İstatistikleri (1990 Energy Statistics). Proceedings of 5th Energy Congress of Turkey, October, 22–26, 1990, Ankara.
WEC-TNC (World Energy Council, Turkish National Committee), 1994. Enerji İstatistikleri (1994 Energy Statistics). Proceedings of 6th Energy Congress of Turkey, October, 17–22, 1994, Izmir.
WEC-TNC (World Energy Council, Turkish National Committee), 1997. Enerji İstatistikleri (1997 Energy Statistics). Proceedings of 7th Energy Congress of Turkey, November, 3–8, 1997, Ankara.
WEC-TNC (World Energy Council, Turkish National Committee), 2002. Enerji İstatikleri (2002 Energy Statistics). Proceedings of 9th Energy Congress of Turkey, September, 24–27, 2002, Istanbul.
WEC-TNC (World Energy Council, Turkish National Committee), 2006. Enerji İstatistikleri (2006 Energy Statistics). Proceedings of 10th Energy Congress of Turkey.
Yüksek, S., Elevli, B., Demirci, A., 2001. Hammadde, kaynak, cevher ve rezerv gibi bazı terimlerin tanımlarına bir yaklaşım: Hasançelebi demir yatağı örneği (A new approach to the terms of raw material, resource and reserve: an example of Hasançelebi iron ore deposists). Jeoloji Mühendisliği 25 (2), 47–54.