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PRODUCTION OF AN INSULATION MATERIAL FROM CARPET AND BORON WASTES

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ABSTRACT

Buildings are large consumers of energy in all countries. In regions with harsh climatic conditions, a substantial share of energy goes to heat and cool buildings. This paper reports an investigation of the insulation materials made from mixing carpet wastes with a solution with added crude colemanite ore, one of boron minerals, and a solution with added colemanite wastes from a barrage. A new building insulation material was produced which is name, Halibor. Optimum mixing ratios were determined for mass production and the physical properties of the product were established. In addition, the material produced was compared with similar products used in buildings in terms of physical properties. As a result of the investigations, it was established that the product provides high heat and sound insulation and can be used easily in building and construction industry.

1. Introduction

Of the total energy produced in the world, 25% is consumed during industrial production, 25% during use of motor vehicles, and 50% in buildings. A very large proportion of the energy consumed in buildings is used for heating or cooling buildings. The efficient use of energy makes a significant contribution to preventing negative environmental impacts. The emission of greenhouse gases, primarily CO_2, causes global warming and along with it, climate change. Thermal insulation enables heating or cooling of buildings with less fuel so greenhouse gases, such as carbon dioxide (CO_2), sulfur dioxide (SO_2), will also be reduced, thus contributing to mitigation of greenhouse effect in the atmosphere, global warming and climate change (Demir and Orhan 2006; Enek, 2012, Erdoğan and Yaşar, 2005).

According to building census of 2000, there are 7.8 million buildings in Turkey. This number is increasing every day in proportion to the rate of population growth and urbanization. According to the census, the area occupied by residential and commercial buildings is 913 million m^2, 400 million m^2 of which is heated. In terms of resource consumption and environmental damage, buildings are responsible for 13.6% of water use, 70% of electricity consumption, 60% of solid waste generation, and 33-39% of greenhouse gas emissions. From the perspective of building life cycle, it is seen that 83% of the total energy is consumed during use of the building. 80% of the energy consumed in households is spent on heating. The efficiency of use of a building and environmental damage caused by it vary depending on its design, the materials used during its construction and efficiency in its operation. Therefore, it is possible to lower energy consumption values and support sustainability by insulation to be implemented in buildings as well as increasing efficiency of building energy systems (Keskin, 2010).

In other words, thermal insulation appears to be an important factor. Reducing building energy demand, thus reducing energy consumption by applying insulation material with high thermal resistance means reducing fossil fuels used for heating as well as fossil fuel-based carbon emissions. In this way, energy-related air pollution can be reduced (Yaşar et al., 2004). In addition, urbanization, industrialization, technological development and population growth

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in our developing world requires an increasingly noisy way of life. Today, noise is expressed as an environmental problem as well as a health issue. To get rid of this problem, people are seeking a quiet and peaceful life as much as possible. In order to reduce noise pollution, living areas with high sound insulation and less noise should be developed. For this reason, the product developed in this study has heat conduction as well as sound insulation properties, providing great advantages in terms of marketing the product (Erdoğan and Yaşar, 2012; Erdoğan, 2007).

A number of research projects have investigated about insulation materials. Aspiras and Manalo (1995) analyzed composites made from textile waste cuttings and Portland cement; and Fisher et al. (2001) studied the suitability of cellulose fibers, Kriker et al. (2004) of palm fibers, Perry (2003) of long and short synthetic fibers, Wong (2004), Meyer et al. (2002) of different kinds of specific and waste fibers, Schmidt and Cieslak (2007) analyzed concrete with carpet recyclates.

In this study has been reported on the development of insulation materials from carpet waste fibers with comparable properties as that of conventional materials. Two different insulating materials were produced by mixing carpet wastes with a solution with added crude colemanite ore, a boron derivative, and a solution with added colemanite wastes from a barrage. The name, HaliBor, was chosen as the designation for the resultant insulation material for use in patent applications. The product (HaliBor) is a low-cost material with high heat and sound insulation values, whose physical and mechanical properties comply with standards in building and construction industry. Moreover, mineralogical advantages of boron and use of idle raw materials enabled the product to be both a fire-resistant and an environmentally friendly material.

2. Materials and methods

2.1. Material

Carpets are complex composite material structures often made from a number of natural or synthetic materials. A typical carpet has four main layers or components. The top layer, or face fiber, represents the main component in the carpet waste and is usually made of wool, nylon or polypropylene (Olivares-Marin and Maroto-Valer, 2011). Weft yarn, warp yarn and pile yarn are used to manufacture carpets. In the province of Gaziantep, where almost half of Turkey's carpet production takes place, it was determined that total wastage and loss of yarns per year amounts to 6-16% for weft yarn, 10-15% for warp yarn and 15-20% for pile yarn. According to information obtained from carpet factories and studies in the literature, annual total amount of carpet waste is approximately 600.000 tonnes. For the national economy, such high amount of carpet waste is a significant loss. Furthermore, carpet edges, threads ripped away from rug underlay and jute yarn generated in carpet factories or plants for cutting carpets are important wastes which are sustainable wastes waiting to be utilized. Main theme of this study was to utilize constantly increasing carpet wastes and use boron, a valuable resource of Turkey, in this sector (Kozak, 2010). During preliminary studies, the state of the carpet wastes of a company operating in carpet making in the province of Gaziantep, was examined and these wastes were found to be generated consistently (Figure 1).

Figure 1- Kinds of carpet waste

Boron is a chemical element shown with symbol B in the periodic table and its atomic number is 5. Other properties of boron are as follows: atomic weight: 10.81, density: 2.84 gr/cm^3, melting point: 2300^{o}C and boiling point: 2550^{o}C. It is a metalloid with semiconductor properties. It is found in the form of compounds with other elements and is not found naturally on Earth. There are about 230 varieties of boron in nature. Since it is susceptible to bonding with oxygen, there is a wide variety of boron-oxygen compounds. Boron-oxygen compounds are generally called borate. Turkey has 72.2% of the world's boron deposits, and mining and processing of high grade boron ores is very easy and cost-effective.

In the study, carpet wastes were mixed with two individual solutions with different concentrations. The first solution contains concentrated colemanite ore with 36.19% of B_2O_3, and the other contains concentrated colemanite waste with 25.77% of B_2O_3. Colemanite ore and concentrated wastes were supplied by Emet Boron Works attached to Directorate- General of Eti Mining, and their chemical composition is given in table 1. Concentrated colemanite wastes are stored in barrage pools inside the facility and are not used. Efforts were made to also use these idle concentrated wastes, which pose an environmental problem, to produce the resultant HaliBor material. After completion of all these procedures, the mixture was pressed and the insulation material was dried (Batar et al., 2009; Yılmaz, 2004). Furthermore, an adhesive called Carboxy Methyl Cellulose (CMC), commonly used in the industry, was used in order to obtain a more robust insulation material, produced from a mixture of carpet wastes and colemanite ore solution.

Table 1- Espey concentrate colemanite ore and chemical analysis of colemanite waste.

Chemical Composition	Concentrate Ore (%)	Espey Colemanite Waste (waste of old dam) (%)
B_2O_3	36,19	25,77
SiO_2	14,6	22,46
Fe_2O_3	1,04	1,51
Al_2O_3	3,84	5,83
CaO	19,83	15,9
MgO	2,46	5,02
TiO_2	3,54	4,84
As(ppm)	205	400
SO_4	0,13	0,18

2.2. Method

Flow diagram for the production of insulation material with added boron from carpet wastes is given in figure 2. As seen in figure 2, first, carpet wastes were cut and torn into pieces. Then, pre-determined amounts of water, colemanite, and CMC and carpet wastes were placed inside a mixer and mixed, after which the resultant product was placed inside a mold, pressed and shaped. Following the pressing procedure, the product was oven-dried at 35°C for 4 hours and became ready for use.

3. Results and Discussion

As a result, two different products which gave optimal values were obtained. The product with added crude colemanite ore was designated as HaliBor-1, and the other with added colemanite barrage waste was designated as HaliBor-2. The resultant materials were designed in dimensions of 40 x 40 x 10 cm (width x length x height).

Physical and mechanical properties of the product (density, thermal conductivity, flame retardency properties and sound insulation values) were determined. In addition, HaliBor-1 and HaliBor-2 were compared with other insulation and construction materials used in building and construction industry. A classification of materials by flame retardency values was made according to the DIN 4112 standard and the results are given in table 2 (DIN 4112, 1960, http://www.termo1numara.com). In view of table-2, it is clear that HaliBor insulation materials gave considerably good results when compared with other materials used in the industry. A density value ranging between 185 and 200 kg/m^3 was obtained.

The insulation material with values comparable to those of HaliBor-1 in the industry is glass wool. HaliBor-1 with added crude ore turned out to be a new insulation material with the lowest density value used in the industry (Figure 3).

Thermal conductivity tests were performed according to TS 825. The results showed that HaliBor-1 and HaliBor-2 gave values of 0.035 λW/(mK) and 0.04 λW/(mK), respectively. When HaliBor with added boron and carpet waste was compared with other materials, it was seen that HaliBor-1 with added crude ore also gave the highest heat insulation value (Figure 4).

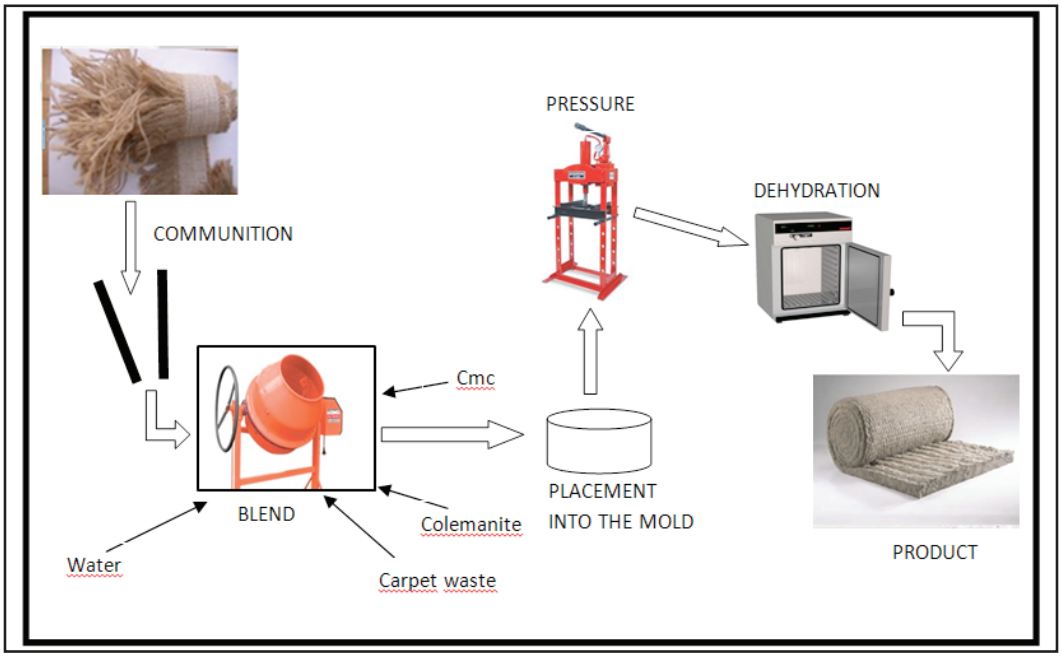

Figure 2- HaliBor production plan.

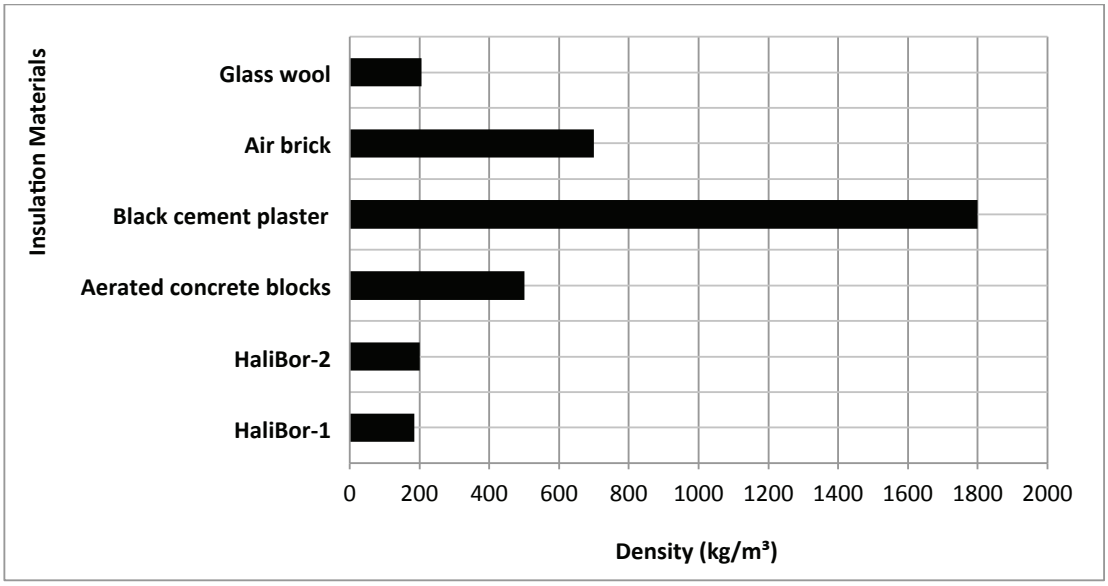

Figure 3- Density values of the sealing materials.

Table 2- Comparison Table of Various Structural Elements (http://www.termo1numara.com).

Insulation Material	Density(kg/m³)	Thermal Conductivity λW/(mK)	Flammability (DIN 4112)	Sound Insulation (dB) (10cm/500hz)
HaliBor-1	185	0,035	B1- Difficult Flaming	38
HaliBor-2	200	0,04	B1- Difficult Flaming	38
Aerated concrete blocks	500	0,14	B1- Difficult Flaming	38
Black cement plaster	1800	0,87	A- Fireproof	35
Air brick	700	0,24	A- Fireproof	37
Glass wool	205	0,04	B1- Difficult Flaming	36

Sound insulation is given by the amount of sound absorbed by the materials to provide insulation in a room with sound insulation where sound is emitted by an amplifier at a certain distance (TS EN ISO 10140-3, 2011). Considering the results obtained, it is clear that HaliBor-1 and 2 were the materials offering the highest insulation along with aerated concrete (Figure 5).

4. Conclusions

In this study, it was understood that carpet wastes with limited use in the industry and concentrated colemanite ore and wastes can be used to generate insulation materials. The insulation material with added crude colemanite ore was designated as HaliBor-1, and the other with added concentrated colemanite wastes was designated as HaliBor-2.

Physical properties of HaliBors were determined and comparisons were made with other insulation materials used in the industry. As a result of such comparisons, it was seen that HaliBors can be used quite easily in building and construction industry. Importance and value of the work was further increased by the fact that waste materials were recycled to obtain a different product.

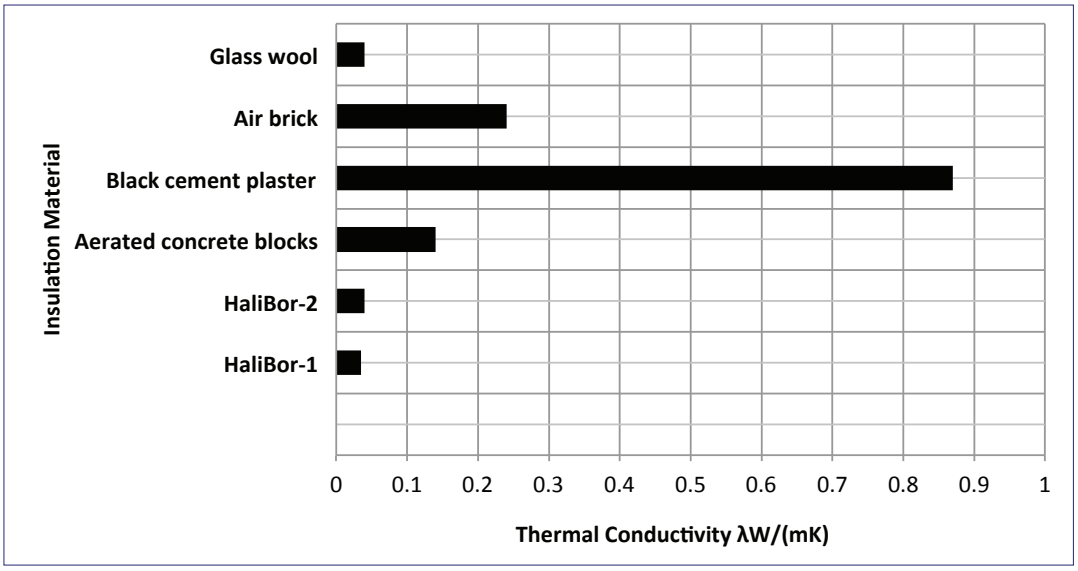

Figure 4- Thermal insulation value of insulation materials.

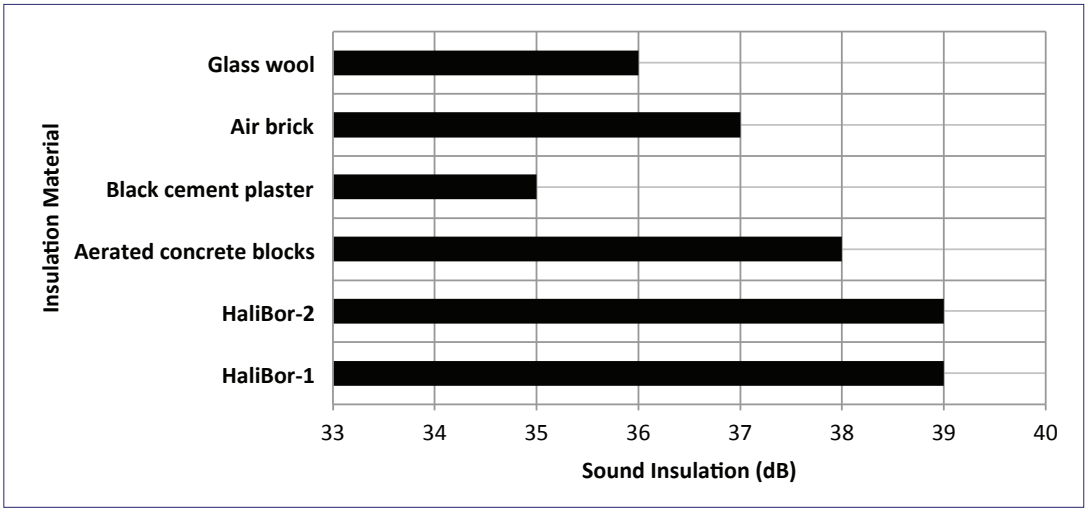

Figure 5- Sound insulation values of insulation materials.

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o Barnes, F., Kaya, O. 1963. İstanbul bölgesinde bulunan Karbonifer'in genel stratigrafisi. *Maden Tetkik ve Arama Dergisi* 61,1-9.

o Robertson, A.H.F. 2002. Overview of the genesis and emplacement of Mesozoic ophiolites in the Eastern Mediterranean Tethyan region. *Lithos* 65, 1-67.

- If more than one document by the same authors is cited, firstly the ones having single name must be placed in chronological order, then the ones having two names must be listed in accordance with chronological order and second author's surname, finally the ones having multiple names must be listed in accordance with chronological order and third author's surname.
- If the document is a book, these are specified respectively: surnames of the author/authors, initial letters of author's/authors' first names. Year of publication. Name of the book (initial letters are capital). Name of the organization which has published the book (in italics), name of the publication wherethe document is published, volume and/ or the issue number, total pages of the book.

For example

o Meric, E. 1983. Foraminiferler. *Maden Tetkik ve Arama Genel Müdürlüğü Eğitim Serisi* 23, 280p.

o Einsele, G. 1992. Sedimentary Basins. *Springer-Verlag*, p 628.

- If the document is published in a book containing the writings of various authors, the usual sequence is followed for the documents in a periodic publication. Then the editor's surname andinitial letters of their name /names are written. "Ed." which is an abbreviation of the editor word is written in parentheses. Name of the book containing the document (initial letters are capital). Name of the organization which has published the book (*in italics*). Place of publication, volume number (issue number, if any) of the publication where the document is published, numbers of the first and last page of the document.

For example:

o Göncüoğlu, M.C., Turhan, N., Şentürk, K., Özcan, A., Uysal, Ş., Yalınız, K. 2000. A geotraverse across northwestern Turkey. Bozkurt, E., Winchester, J.A., Piper, J.D.A. (Ed.). Tectonics and Magmatism in Turkey and the Surrounding Area. *Geological Society of London* Special Publication 173, 139-162.

o Anderson, L. 1967. Latest information from seismic observations. Gaskell, T.F. (Ed.). The Earth's Mantle. Academic Press. London, 335-420.

- If name of a book where various authors' writings have been collected is specified, those must be indicated respectively: book'seditor/editors' surname/surnames, and initial letters of their name/names. "Ed." which is an abbreviation of the editor word must be written in parentheses. Year

of Publication. Name of the book (initial letters are capital). Name of the organization which has published the book (*in italics*), total pages of the book.

For example:

o Gaskel, T.F.(Ed.)1967. The Earth's Mantle. *Academic Press*, 520p.

- If the document is an abstract published in a Proceedings Book of a scientific activity such as conference/symposium/workshop …etc., information about the document must be given in the following order: surnames of the author/ authors, initial letters of author's/authors' first names. Year of publication. Title of the abstract. Name (in italics), date and place of the meeting where the Proceedings Book is published, numbers of the first and last pages of the abstract in the Proceedings Book.

For example:

o Yılmaz, Y. 2001. Some striking features of the Anatolian geology. *4. International Turkish Geology Symposiums,* 24-28 September 2001, London, 13-14.

o Öztunalı, Ö., Yeniyol, M. 1980. Yunak (Konya) yöresi kayaçlarının petrojenezi. *Türkiye Jeoloji Kurumu 34. Bilim Teknik Kurultayı*, 1980, Ankara, 36

- If the document is unpublished documents as report, lecture notes, and so on., information about the document must be given by writing the word "unpublished" in parentheses to the end of information about the document after it is specifiedin accordance with usual order which is implemented for a document included in a periodic publication.

For example:

o Özdemir, C. Biçen, C. 1971. Erzincan ili, İliç ilçesi ve civarı demir etütleri raporu. *General Directorate of Mineral Research and Exploration Report No: 4461*, 21 p. Ankara (unpublished).

o Akyol, E. 1978. Palinoloji ders notları. *EÜ Fen Fakültesi Yerbilimleri Bölümü*, 45 p., İzmir (unpublished).

- The followings must be specified for the notes of unpublished courses, seminars, and so on: name of the document and course organizer. Place of the meeting. Name of the book, corresponding page numbers.

For example:

o Walker, G. R. Mutti, E. 1973.Turbidite facies and facies associations. Pacific Section Society for Sedimentary Geology Short Course. Annaheim. Turbitides and Deep Water Sedimantation, 119-157.

- If the document is a thesis, the following are written: surname of the author, initial letter of the author's first name. Year of Publication. Name of the thesis. Thesis type, the university where it is given, the total number of pages, the city and "unpublished" word in parentheses.

For example:

o Seymen, İ. 1982. Kaman dolayında Kırşehir Masifi'nin jeolojisi. Doçentlik Tezi, İTÜ Maden Fakültesi, 145 s.İstanbul (unpublished).

- Anonymous works must be regulated according to publishing organization.

For example:

o MTA. 1964. 1/500.000 ölçekli Türkiye Jeoloji Haritası, İstanbul Paftası. Maden Tetkik ve Arama Genel Müdürlüğü, Ankara.

- The date, after the name of the author, is not given for on-printing documents; "in press" and / or "on review" words in parenthesis must be written. The name of the article and the source of publication must be specified, volume and page number must not be given.

For example:

o Ishihara, S. The granitoid and mineralization. Economic Geology 75th Anniversary (in press).

- Organization name, web address, date of access on web address must be indicated for the information downloaded from the Internet. Turkish sources must be given directly in Turkish and they must be written with Turkish characters.

For example:

o ERD (Earthquake Research Department of Turkey). **http://www.afad.gov.tr**. March 3, 2013.

- While specifying work cited, the original language must be used; translation of the title of the article must not be done.

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- All drawings, photographs, plates and tables of the article are called "illustration".
- Illustrations must be used when using them is inevitable or they facilitate the understanding of the subject.
- While selecting and arranging the illustrations' form and dimensions, page size and layout of the *Bulletin* must be considered, unnecessary loss of space must be prevented as much as possible.
- The pictures must have high quality, high resolution suitable for printing.
- The number of illustrations must be proportional to the size of the text.
- All illustrations must be sent as separate files independent from the text.
- While describing illustrations in the text, abbreviations must be avoided and descriptions must be numbered in the order they are mentioned in the text.
- Photographs and plates must be given as computer files containing EPS, TIFF, or JPEG files in 600 dpi and higher resolutions (1200 dpi is preferred) so that all details can be seen in the stage of examination of writing.

6.1. Figures

- Drawings and photos together but not the plate in the text can be evaluated as "Figure" and they must be numbered in the order they are mentioned in the text.
- The figures published in the *Bulletin of Mineral Research and Exploration* must be prepared in computing environment considering the dimensions of single-column width 7.4 cm or double-column width 15.8 cm. Figure area together with the writing at the bottom should not exceed a maximum 15.8x21.
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- Figures must be arranged to be printed in black-and-white or colored. The figure explanations being justified in two margins must be as follows:

Figure 1 -Sandıklı Town (Afyon); a) Geological map of thesouth-west, b) general columnar section of the study area (Seymen 1981), c) major neotectonic structures in Turkey (modified from Koçyiğit 1994).

- Drawings must be drawn by well-known computer programs painstakingly, neatly and cleanly.
- Using fine lines which can disappear when figures shrinks must be avoided. Symbols or letters used in all drawings must be Times New Roman and not be less than 2 mm in size when shrink.
- All the standardized icons used in the drawings must be explained preferably in the drawing or with figure caption if they are very long.
- Linear scale must be used for all drawings. Author's name, figure description, figure number must not be included into the drawing.
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6.2. Plates

- Plates must be used when needed a combination of more than one photo and the publication on a special quality paper.
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- The original plates must be added to the final copy which will be submitted if the article is accepted.
- Figures and plates must be independently numbered. Figures must be numbered with Latin numerals and plates with Roman numerals (e.g., Figure1, Plate I).
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- Tables must be numbered consecutively in accordance with their appearence in the text.
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Table 1- Hydrogeochemical analysis results of geothermal waters in the study area.

7. Nomenclature and Abbreviations

- Non-standard and uncommon nomenclature abbreviations should be avoided in the text. But if essential, they must be described as below: In cases where unusual nomenclatures and unstandardized abbreviations are considered to be compulsory, the followed way and method must be described.
- Full stop must not be placed between the initials of words for standardized abbreviations (MER, SHW, etc.).
- Geographical directions must be abbreviated in English language as follows: N, S, E, W, NE …etc.
- The first time used abbreviations in the text are presented in parenthesis, the parenthesis is not used for subsequent uses.
- The metric system must be used as units of measure.
- Figure, plate, and table names in the article must not be abbreviated. For example, "as shown in generalized stratigraphic cross-section of the region (Figure 1……..."

7.1. Stratigraphic Terminology

Stratigraphic classifications and nomenclatures must be appropriate with the rules of International Commision on Stratigraphy and/or Turkey Stratigraphy Committee. The formation names which has been accepted by International Commision on Stratigraphy and/or Turkey Stratigraphy Committee should be used in the manuscript.

7.2. Paleontologic Terminology

Fossil names in phrases must be stated according to the following examples:

o For the use authentic fossil names:

e.g. Calcareous sandstone with *Nummulites*

o When the authentic fossil name is not used.

e.g. nummulitic Limestone

o Other examples of use;

e.g. The type and species of Alveolina/ Alveolina type and species

- Taxonomic ranks must be made according to following examples:

Super family: Alveolina Ehrenberg, 1939 Family: Borelidae Schmarda, 1871 Type genus: *Borelis* de Montfort, 1808 Type species: *Borelis melenoides de Montfort, 1808*; *Nautilus melo* Fitchel and Moll, 1789	*Not reference, Not stated in the Reference section*
Borelis vonderschmitti (Schweighauser, 1951) (Plate, Figure, Figure in Body Text)	*Schweighauser, 1951 not reference*
1951 *Neoalveolina vonderschmitti* Schweighauser, page 468, figure 1-4	*Cited Scweighauser (1951), stated in the Reference section.*
1974 *Borelis vonderschmitti* (Schweighauser), Hottinger, page, 67, plate 98, figure 1.7	*Cited Hottinger (1974), stated in the Reference section.*

- The names of the fossils should be stated according to the rules mentioned below:

o For the first use of the fossil names, the type, spieces and the author names must be fully indicated

Alveolina aragoensis Hottinger

Alveolina cf. Aragoensis Hottinger

o When a species is mentioned for the second time in the text:

A.aragoensis

A.cf.aragoensis

A.aff.aragoensis

o It is accepted as citiation if stated as *Alveolina aragoensis* Hottinger (1966)

- The statment of plates and figures (especially for articles of paleontology):

o for statment of the species mentioned in the body text

Borelis vonderschmitti (Schweighauser, 1951).

(plate, figure, figure in the body text).

o When citing from other articles

1951 Neoalveolina vonderschmitti Schweighauser, page 468, figure 1-4, figure in body text

1974 *Borelis vonderschmitti* (Schweighauser), Hottinger, page 67, plate 98, figure 1-7

- For the citiation in the text

- (Schweighauser, 1951, page, plate, figure, figure in the body text) (Hottinger, 1974, page, plate, figure 67, plate 98, figure 1-7, figure in the bodytext.)

8. Citations

All the citiations in the body text must be indicated by the last name of the author(s) and the year of publication, respectively. The citations in the text must be given in following formats.

- For publications written by single author:

- It is known that fold axial plain of Devonian and Carboniferious aged units around Istanbul is NS oriented (Ketin, 1953, 1956; Altınlı, 1999).

- Altınlı (1972, 1976) defined the general characteristics of Bilecik sandstone

- For publications written by two authors:

- The upper parts of the unit contain Ilerdian fossils (Sirel and Gündüz, 1976; Keskin and Turhan, 1987, 1989).

- For publications written by three or more authors:

According to Caner et al. (1975) Alıcı formation reflects the fluvial conditions.

The unit disappears wedging out in the East direction (Tokay et al., 1984).

- If reference is not directly obtained but can be found in another reference, cross-reference should be given as follows:

- It is known that Lebling has mentioned the existance of Lias around Çakraz (Lebling, 1932: from Charles, 1933).

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