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*Geology of the Pieniny Klippen Belt and the Tatra Mts, Carpathians*
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*Part XIX*

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# Lower Cretaceous exotic intraplate basaltoid olistolith from Biała Woda, Pieniny Klippen Belt, Poland: geochemistry and provenance[3]

(Figs 1–8, Tab. 1)

**Abstract.** Geochemical analysis of a basaltic olistolith, K-Ar dated at Lower Cretaceous, which occurs in Upper Cretaceous conglomerates (Jarmuta Formation) of the Pieniny Klippen Belt of Poland, points to trachybasalt field of intraplate basaltoids. The olistolith most probably derived from a volcanic structure located on the Czorsztyn Ridge – a lithospheric splinter of the North European Platform which, during Jurassic–Early Cretaceous, bordered the Pieniny Klippen Belt Basin from the north.

**Key words:** Lower Cretaceous, intraplate basaltoid, olistolith, Pieniny Klippen Belt, Carpathians.

## GEOLOGICAL SETTING AND AGE OF BASALTIC ROCK

A unique basaltic exposure occurs at Biała Woda in the Pieniny Klippen Belt of Poland (West Carpathians). It forms a small "klippe" up to 3.5 m high and c. 7×8 m in horizontal plane – Figs 1–4. Since its discovery by Horwitz (1926), it was generally treated as a small Tertiary intrusion (e.g., Birkenmajer, 1954, 1958a, b, 1963, 1979). This seemed to be in agreement with results of magnetometric surveys performed in the area of Biała Woda by Małoszewski (1968). However, palaeomagnetic investigation (Birkenmajer & Nairn, 1969) failed to support this.

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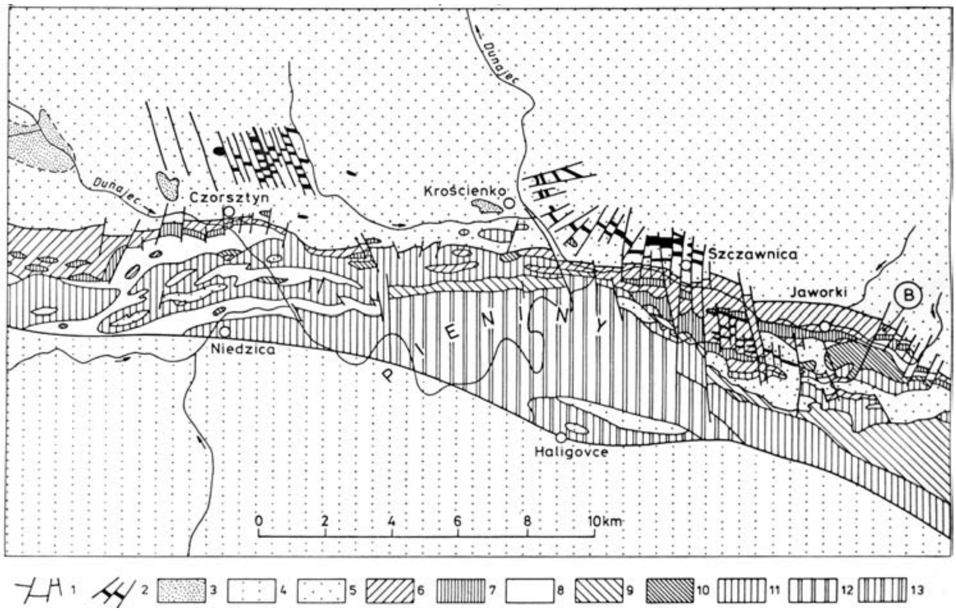


**Fig. 1.** Location of the Early Cretaceous basaltoid olistolith (**B**) aganist structural elements of the Pieniny Klippen Belt in Poland. *1* – Middle Miocene faults; *2* – Middle Miocene andesite intrusions; *3* – fresh-water Neogene deposits; *4* – Podhale Palaeogene flysch (autochthonous) and Podhale-type Palaeogene in the Pieniny Klippen Belt; *5* – Magura Nappe (Cretaceous–Palaeogene flysch deposits) and autochthonous uppermost Cretaceous–Palaeogene deposits in the Pieniny Klippen Belt; *6*, *7* – Grajcarek Unit (*6* – Upper Cretaceous deposits; *7* – Jurassic–Lower Cretaceous deposits); *8–13* – Klippen tectonic units, Mesozoic (*8* – Czorsztyn Unit; *9* – Czertezik Unit; *10* – Niedzica Nappe; *11* – Branisko Nappe; *12* – Pieniny Nappe; *13* – Haligovce Nappe)

It was Rabowski (in Horwitz & Rabowski, 1929, pp. 38, 48) who first suggested that the basalt represents a block in the surrounding "Jarmuta conglomerate". Radiometric dating by M. M. Arakelyants (reported by T. Wieser in 1987 – see Birkenmajer & Wieser, 1990, footnote, p. 49; Birkenmajer, 1996, p. 22; Birkenmajer & Pécskay, 2000, p. 28), yielded an Early Cretaceous 140±8 Ma K-Ar date close to the Jurassic/Cretaceous boundary. Two more radiometric datings, obtained from both columnar-jointed and platy-jointed parts of the basaltic rock, yielded 110.6± 4.2 and 120.3±4.5 Ma Early Cretaceous (Aptian–Albian) K-Ar ages, respectively. This was a good confirmation of Rabowski's view that we deal here with a large block in conglomerates of the Jarmuta Formation.

## PETROGRAPHY AND GEOCHEMISTRY

**Previous studies.** In thin plates from the basaltic rock, Kamieński (1931) recognized phenocrysts of orthoclase and plagioclase, pyroxene (diopsidic augite), biotite, amphibole (basaltic hornblende), moreover Fe-oxides and apatite. Calcite-

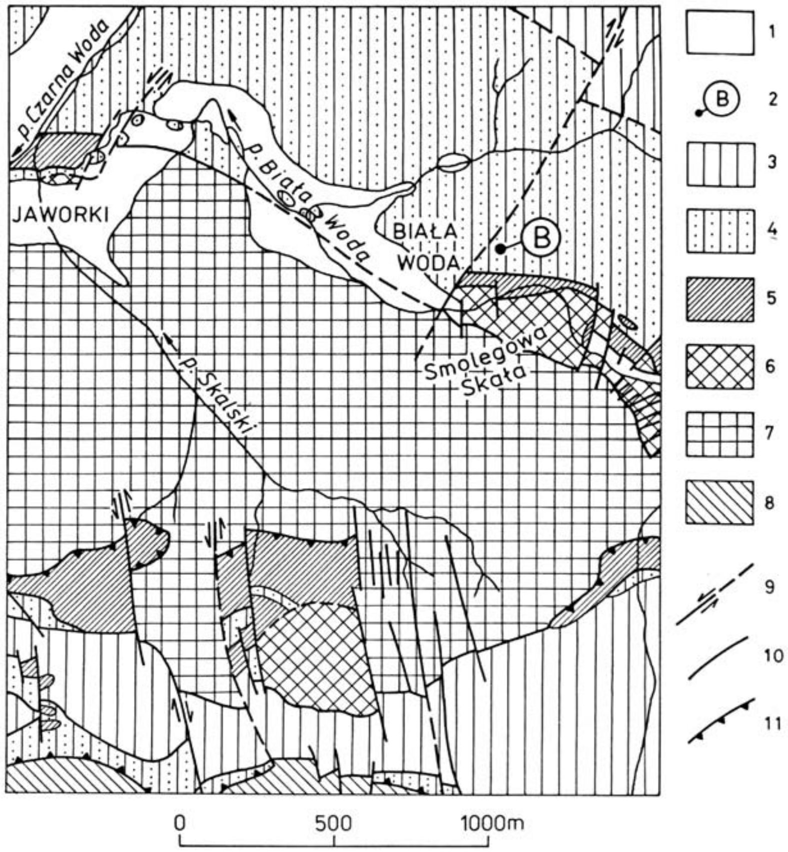


**Fig. 2.** Location of the basaltoid olistolith at Biała Woda, Pieniny Klippen Belt of Poland (geology after Birkenmajer, 1979, simplified). *1* – Quaternary cover; *2* – basaltoid olistolith; *3* – Magura Palaeogene; *4*, *5* – Grajcarek Unit (*4* – Jarmuta Fm. and Malinowa Shale Fm.; *5* – Jurassic–Lower Cretaceous deposits); *6* – Czorsztyn Unit; *7* – Niedzica Nappe; *8* – Branisko Nappe; *9* – faults; *10* – Tertiary overthrusts; *11* – Late Cretaceous overthrusts

filled olivine pseudomorphs were also found. Chlorite and calcite were the main secondary minerals.

**Present studies.** The basaltic rock is very fine-crystalline, dark-grey to black if fresh, devoid of fluidal structure. Small vesicles, 0.1–1.5 mm in diameter, are usually filled with calcite: locally they form an amygdaloidal structure.

Two basaltic rock samples were analysed: sample Ebwb-1 was taken from the platy-jointed part of the basaltic exposure (originally, probably a lava flow), and sample Ebwb-2 from the columnar-jointed one (originally, probably a plug-type intrusion). Groundmass of both samples is similar, consisting of very fine plagioclase and pyroxene. Strong alteration of these minerals preclude their more precise determination. Chloritized glass and numerous grains of opaque minerals, mainly iron-oxides, form the matrix.

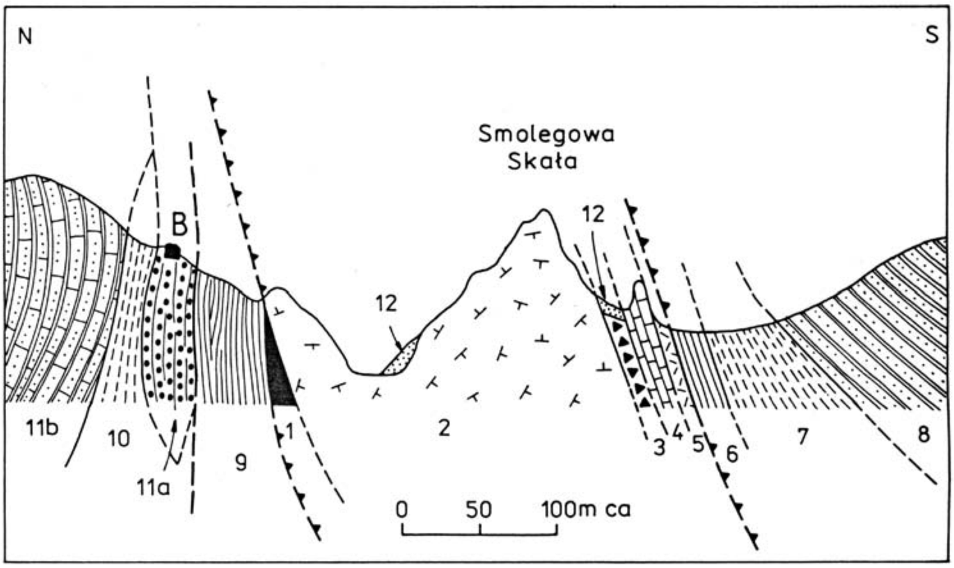


**Fig. 3.** Position of the Biała Woda basaltoid olistolith in geological cross-section (geology after Birkenmajer, 1963, pl. XXIII, fig. 3, modified; see also Birkenmajer & Wieser, 1990, fig. 3A, modified). **Czorsztyn Succession:** 1 – Skrzypny Shale Fm. (Aalenian–Bajocian); 2 – Smolegowa Limestone Fm. (Bajocian); 3 – Krupianka Limestone Fm. (Bajocian–Bathonian); 4 – Czorsztyn Limestone Fm. (Callovian–Lower Tithonian); 5 – Dursztyn Limestone Fm. (Tithonian–Berriasian). **Niedzica Succession:** 6 – Kapuśnica Fm. (?Barremian–Albian); 7 – Jaworki Fm. (Upper Albian–Santonian); 8 – Sromowce Fm. (Santonian–Campanian). **Grajcarek Succession**: 9 – Szlachtowa Fm. (Toarcian–Aalenian); 10 – Malinowa Shale Fm. (Cenomanian–Campanian); 11a, b – Jarmuta Fm. (Maastrichtian: 11a – exotic-bearing conglomerate; 11b – flysch deposits; **B** – basaltoid olistolith). **Quaternary cover**: 12 – talus

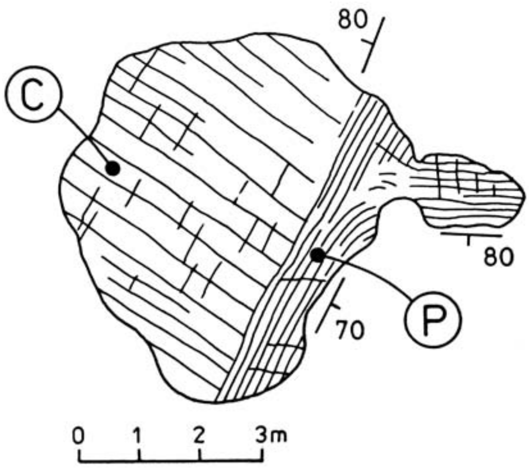


**Fig. 4.** Basaltoid olistolith block at Biała Woda (after Birkenmajer, 1958a). C – columnar-jointed; P – platy-jointed; strikes and dips denote tilts of thermal jointing

**Fig. 5.** Exposure of basaltoid olistolith ("klippe") at Biała Woda (*phot. L. Chudzikiewicz*)

**Sample Ebwb-1** represents a nearly homogenous volcanic rock almost devoid of phenocrysts: the latter, if present, are slightly larger than the groundmass, and represent a thoroughly sericitized plagioclase. Secondary calcite is very common.

**Sample Ebwb-2** shows the presence of single phenocrysts, less than 1 mm in size, originally representing some mafic minerals: presently, they are entirely chloritized. Groundmass of this sample is slightly coarser than that of sample Ebwb-1.

**Results.** Mineral composition of both samples, and contents and ratios of their immobile trace elements (Tab. 1), point to the trachybasalt field (Fig. 6). In the TAS diagramme (Fig. 7) both samples plot in the basanite field, however their mineral composition does not support this. Discrimination diagram, based upon contents of the ratios Zr/Y vs Ti/Y (Fig. 8) clearly shows that our rocks are typical within-plate basaltoids.

## EARLY CRETACEOUS VOLCANISM IN THE PIENINY KLIPPEN BELT AND ITS VICINITY

**Hightatric units.** Manifestations of Early Cretaceous volcanism are known from numerous sites in the Inner West Carpathians (see review by Mišík, 1992).

**Table 1**

Chemical composition of the intraplate basaltic olistolith from Biała Woda, Pieniny Klippen Belt (Poland)
Courtesy of Dr Jacek Grabowski, Polish Geological Institute, Warszawa

| | Ebwb-1 | Ebwb-2 | | Ebwb-1 | Ebwb-2 |
|---|---|---|---|---|---|
| | % | | | ppm | |
| $SiO_2$ | 43.12 | 41.70 | Hf | 9 | 7 |
| $TiO_2$ | 3.04 | 3.19 | La | 54 | 52 |
| $Al_2O_3$ | 14.09 | 13.89 | Mo | 7.3 | 5.9 |
| $Fe_2O_3$ | 12.44 | 12.34 | Nb | 103 | 101 |
| MnO | 0.18 | 0.14 | Ni | 86 | 101 |
| MgO | 9.09 | 9.03 | Pb | 3 | 3 |
| CaO | 6.37 | 6.63 | Rb | 53 | 51 |
| $Na_2O$ | 1.86 | 1.73 | Sr | 874 | 608 |
| $K_2O$ | 2.80 | 2.91 | Ta | 9 | 10 |
| $P_2O_5$ | 0.87 | 0.93 | Th | 7 | 7 |
| LOI | 5.56 | 7.08 | U | 3.5 | 3.8 |
| SUM | 99.58 | 99.58 | V | 139 | 167 |
| | ppm | | W | 5 | 5 |
| As | 11 | 8 | Y | 34 | 33 |
| Ba | 568 | 832 | Zn | 113 | 117 |
| Bi | 3 | 3 | Zr | 500 | 471 |
| Ce | 133 | 139 | Ti | 18195 | 19118 |
| Co | 31 | 33 | Ti/Y | 535 | 579 |
| Cr | 123 | 183 | Zr/Y | 14.7 | 14.3 |
| Cu | 28 | 28 | R1 | 1169 | 1409 |
| Ga | 21 | 21 | R2 | 1093 | 1430 |

Close to the Pieniny Klippen Belt, they are associated mainly with the Hightatric units *sensu lato*:

(1) At Osobita Mount, Western Tatra Mts, limburgite lavas (and hyalobasanites) are associated with limestones containing brachiopods *Pygope diphya* (Col.). They were attributed by Kotański & Radwański (1959) to Middle Tithonian, by Lefeld (in Lefeld *et al.*, 1985, pp. 29–32, fig. 12) – to the Sobótka Limestone Member (Tithonian) of the Raptawicka Turnia Limestone Formation (Callovian–Hauterivian), and by Mišík (1992, p. 53) to the Berriasian;

(2) In the Middle Váh River Valley (Stražovské vrchy Mts, Western Slovakia) Barremian–Aptian volcanics occur in klippes of the Manín Unit (*s.s.*) (e.g., Mišík, 1992, p. 53) – another Hightatric-type unit.

**Pieniny Klippen Belt Basin.** In the Pieniny Klippen Belt, which separates the Inner from the Outer Carpathians, expressions of the Early Cretaceous volcanism are known from:

(1) The Transcarpathian Ukraine near Novoselica. In exposures at Bolshoy

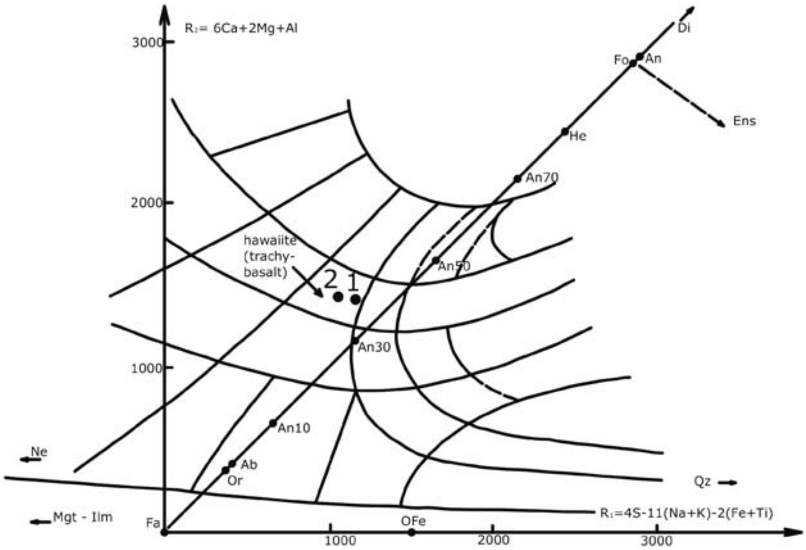


**Fig. 6.** Plot of the Biała Woda olistolith samples in the $R_1$-$R_2$ classification diagramme of de la Roche *et al.* (1980)

Kamenec (Velyky Kamenets), basic rocks (K-diabases, amygdaloids and agglomerates) associated with "Tithonian" limestones (main part of the so-called "Neresnica marble") were recognized in rock sections attributable to the Czorsztyn Succession (Andrusov, 1945, pp. 35–36; Mišík, 1992, p. 51). This part of the "Neresnica marble" is of Berriasian–Valanginian age (Mišík, 1992, p. 51). Krobicki *et al.* (2008) included these volcanics, and the ones exposed in the nearby Vulchovchyk brook, to alkali basalts indicating a "within-plate tectonic environment of the volcanism".

(2) Pieniny Klippen Belt of Poland, eastern part. At Biała Woda, the Early Cretaceous (Aptian–Albian) intraplate volcanic event is represented by basaltoid olistolith block in marine Maastrichtian conglomerate (Jarmuta Formation) of the Grajcarek Unit (see previous chapters). Its large size suggests derivation from marine cliff built up of rocks of the Czorsztyn Ridge (cf. Birkenmajer, 1970), the Lower Cretaceous volcanics inclusively. The volcanism was there subsequent to Neocimmerian (Birkenmajer, 1983c, 1963) disintegration by submarine faulting of a splinter of the North European Platform – the Czorsztyn Ridge and its southern submarine slope (Birkenmajer 1986a, b, 1988).

## CONCLUSIONS

(1) The basaltoid olistolith from the Maastrichtian conglomerate (Jarmuta Formation) in the Grajcarek Unit at Biała Woda is an evidence of Early Cretaceous (Aptian–Albian) intraplate volcanic activity within the Czorsztyn Ridge.

(2) The Early Cretaceous volcanism along the northern margin of the Pieniny

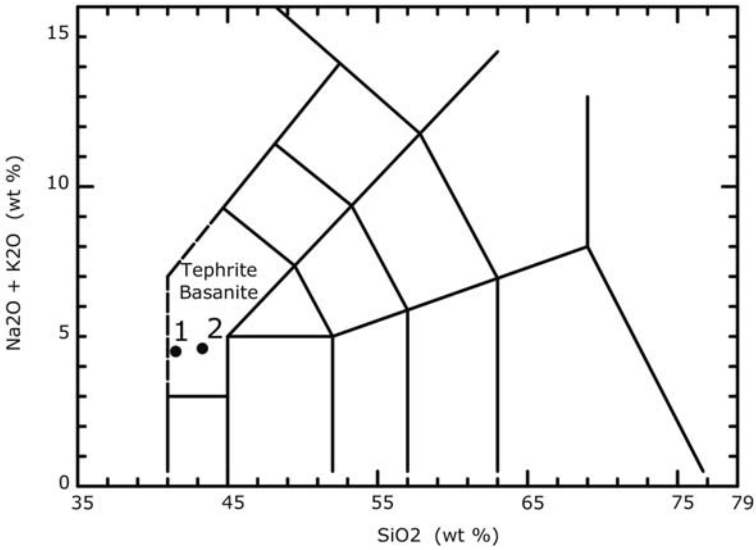


**Fig. 7.** Plot of the Biała Woda olistolith samples in the TAS clasification diagramme

Klippen Basin, associated directly (Transcarpathian Ukraine) or indirectly (Biała Woda) with the Czorsztyn Succession deposits, was related to disintegration by tensional deep-seated gravity faulting of the Czorsztyn Ridge crustal splinter that released mantle-derived magma.

(3) The Early Cretaceous (Aptian–Albian) tensional event terminated the Neocimmerian epoch of uplift and fragmentation by gravity faulting of intra-oceanic ridges in northern part of the Tethys.

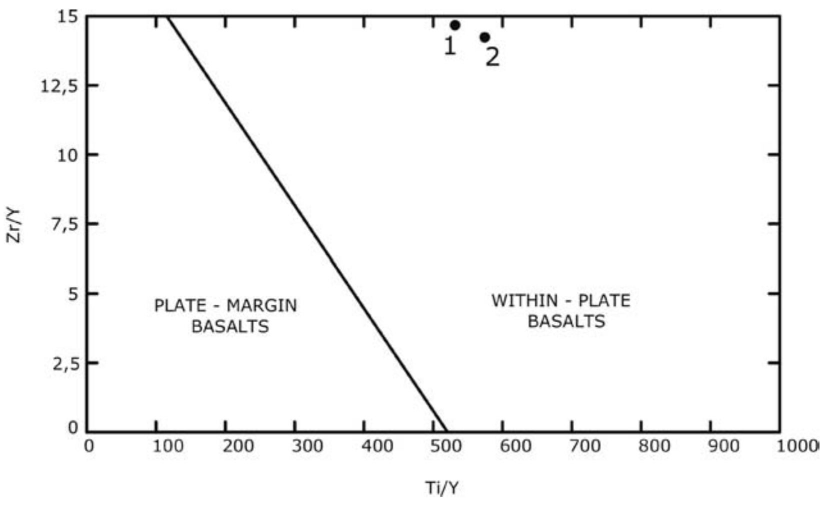


**Fig. 8.** Plot of the Biała Woda olistolith samples in the classification diagramme of Pearce and Gale (1977)

(4) The Early Cretaceous intraplate volcanism in the Czorsztyn Succession/ Ridge area died-out at the northern margin of the Pieniny Klippen Belt Basin, approximately at the same time (Aptian–Albian) as the subduction-related volcanism had started along the southern margin of the Basin, following its subduction under the Exotic Andrusov Ridge.

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