AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Preliminary chemical and isotopic characterization of high-altitude spring waters from eastern Nepal Himalaya

This is a pre print version of the following article:

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/147787> since 2016-06-01T15:39:26Z

Publisher:

Springer International Publishing

Published version:

DOI:10.1007/978-3-319-09300-0_19

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

Metadata of the chapter that will be visualized in SpringerLink

Book Title	Engineering Geology for Society and Territory - Volume 1	
Series Title		
Chapter Title	Preliminary Chemical and Isotopic Characterization of High-Altitude Spring Waters from Eastern Nepal Himalaya	
Copyright Year	2014	
Copyright HolderName	Springer International Publishing Switzerland	
Corresponding Author	Family Name	Costa
	Particle	
	Given Name	Emanuele
	Prefix	
	Suffix	
	Division	Department of Earth Sciences
	Organization	University of Torino
	Address	10125, Turin, Italy
	Email	emanuele.costa@unito.it
Author	Family Name	Destefanis
	Particle	
	Given Name	Enrico
	Prefix	
	Suffix	
	Division	Department of Earth Sciences
	Organization	University of Torino
	Address	10125, Turin, Italy
	Email	
Author	Family Name	Groppa
	Particle	
	Given Name	Chiara
	Prefix	
	Suffix	
	Division	Department of Earth Sciences
	Organization	University of Torino
	Address	10125, Turin, Italy
	Email	
Author	Family Name	Mosca
	Particle	
	Given Name	Pietro
	Prefix	
	Suffix	
	Division	
	Organization	IGG – CNR
	Address	10125, Turin, Italy

	Email	
Author	Family Name	Kaphle
	Particle	
	Given Name	Krishna P.
	Prefix	
	Suffix	
	Division	
	Organization	Nepal Geological Society
	Address	Kathmandu, Nepal
	Email	
Author	Family Name	Rolfo
	Particle	
	Given Name	Franco
	Prefix	
	Suffix	
	Division	Department of Earth Sciences
	Organization	University of Torino
	Address	10125, Turin, Italy
	Division	
	Organization	IGG – CNR
	Address	10125, Turin, Italy
	Email	franco.rolfo@unito.it
Abstract	<p>Metamorphic degassing from active collisional orogens supplies a significant fraction of CO₂ to the atmosphere, thus playing a fundamental role even in today's Earth carbon cycle. Appealing clues for a contemporary metamorphic CO₂ production in active orogens are represented by the widespread occurrence, along the whole Himalayan belt, of CO₂ rich hot-springs mainly localized along major tectonic discontinuities. In contrast to these well-studied hot-springs, almost no chemical and isotopic data are actually available for cold-springs, especially for those located at high-altitude and in remote areas of the Himalayas. In the framework of the Ev-K2-CNR SHARE (Stations at High Altitude for Research on the Environment) Project, we have started a preliminary chemical and isotopic study on high-altitude cold-springs located at different structural levels in the eastern Nepal Himalayas. Chemical and isotopic data obtained from the high-altitude cold-springs are compared with those obtained by previous authors from hot-springs located along the MCT. The isotopic signature of stable isotopes of hydrogen and oxygen could help to identify the waters sources in the investigated Himalayan sectors, to individuate mixing phenomena between waters of different provenience and possible connection with different circulation nets. These first measurements on high-altitude springs from remote areas of eastern Nepal represent a first step towards a better definition of a reliable scenario of water resources availability and will contribute to the understanding of the water cycle in the studied area.</p>	
Keywords (separated by '-')	High-altitude springs - Chemical and isotopic study - Eastern himalayas - Hydrological cycle - Global carbon cycle

Preliminary Chemical and Isotopic Characterization of High-Altitude Spring Waters from Eastern Nepal Himalaya

Emanuele Costa, Enrico Destefanis, Chiara Groppo, Pietro Mosca, Krishna P. Kaphle, and Franco Rolfo

Abstract

Metamorphic degassing from active collisional orogens supplies a significant fraction of CO₂ to the atmosphere, thus playing a fundamental role even in today's Earth carbon cycle. Appealing clues for a contemporary metamorphic CO₂ production in active orogens are represented by the widespread occurrence, along the whole Himalayan belt, of CO₂ rich hot-springs mainly localized along major tectonic discontinuities. In contrast to these well-studied hot-springs, almost no chemical and isotopic data are actually available for cold-springs, especially for those located at high-altitude and in remote areas of the Himalayas. In the framework of the Ev-K2-CNR SHARE (Stations at High Altitude for Research on the Environment) Project, we have started a preliminary chemical and isotopic study on high-altitude cold-springs located at different structural levels in the eastern Nepal Himalayas. Chemical and isotopic data obtained from the high-altitude cold-springs are compared with those obtained by previous authors from hot-springs located along the MCT. The isotopic signature of stable isotopes of hydrogen and oxygen could help to identify the waters sources in the investigated Himalayan sectors, to individuate mixing phenomena between waters of different provenience and possible connection with different circulation nets. These first measurements on high-altitude springs from remote areas of eastern Nepal represent a first step towards a better definition of a reliable scenario of water resources availability and will contribute to the understanding of the water cycle in the studied area.

Keywords

High-altitude springs • Chemical and isotopic study • Eastern himalayas • Hydrological cycle • Global carbon cycle

19.1 Introduction and Aim of the Study

Mountain ranges have strong impact on the global carbon cycle: metamorphic degassing from active collisional orogens, in fact, supplies a significant fraction of the global solid-Earth derived CO₂ to the atmosphere, thus playing a fundamental role even in today's Earth carbon cycle (Evans 2011; Rolfo et al. 2014). Appealing clues for a contemporary metamorphic CO₂ production in active orogens are represented by the widespread occurrence, along the whole Himalayan belt, of CO₂ rich hot-springs mainly localized along the major tectonic discontinuities, such as the Main Central Thrust (Becker et al. 2008; Perrier et al. 2009). Peak

E. Costa (✉) · E. Destefanis · C. Groppo · F. Rolfo
Department of Earth Sciences, University of Torino,
10125 Turin, Italy
e-mail: emanuele.costa@unito.it

F. Rolfo
e-mail: franco.rolfo@unito.it

P. Mosca · F. Rolfo
IGG – CNR, 10125 Turin, Italy

K. P. Kaphle
Nepal Geological Society, Kathmandu, Nepal

values of the measured CO_2 flux at these gas discharges are exceptionally high and similar to values reported on volcanoes ($19,000 \text{ g m}^{-2} \text{ day}^{-1}$; Perrier et al. 2009). In contrast to these well-studied hot-springs, almost no chemical and isotopic data are actually available for cold-springs, especially for those located at high-altitude and in remote areas of the Himalayas.

In the framework of the Ev-K2-CNR SHARE (Stations at High Altitude for Research on the Environment) Project, we have started a preliminary chemical and isotopic study on high-altitude cold-springs located at different structural levels in the eastern Nepal Himalayas (Khimti Khola, Likhu Khola and Dudhkund Khola catchments). Preliminary chemical and isotopic data obtained from these high-altitude cold-springs are hereby compared with those obtained by previous authors from hot-springs located along the Main Central Thrust.

These first measurements on high-altitude springs represent a first step towards a better definition of a reliable scenario of water resources availability and will contribute to the understanding of the water cycle in the studied area.

19.2 Sampling and Analytical Methods

19.2.1 Sampling

Eleven spring water samples were collected in the Numbur and Dudh Khunda region of eastern Nepal Himalayas in the post-monsoon season, November 2012. The investigated springs are located in the Khimti Khola, Likhu Khola and Dudhkhund Khola catchments (tributaries of the Sun Khosi river), at an altitude between 1,800 and 4,500 m a.s.l. (Fig. 19.1). Most of the springs are located in remote areas, far from villages and accessible through poorly known trails. Water sampling was further complicated by the high altitude environment and by the fact that, due to logistic reasons, the amount of collected water had to be minimized.

Temperature and pH were measured *in situ* at the source vents using an HANNA HI2211 pH meter, calibrated every morning with pH standards. Conductivity was measured with an HANNA HI8820 N. Water samples for chemical and isotopic analysis were collected in two polyethylene bottles of 250 ml, capped without head space to minimize degassing. The water samples to be used for DIC isotopic analysis were added with SrNO_3 and NaOH to precipitate all the dissolved inorganic carbon as SrCO_3 , as suggested in

Fig. 19.1 Simplified geological map of the central-eastern sector of the Numbur and Dudh Khunda area, eastern Nepal Himalaya (modified from Mosca et al. 2013) showing sample locations. *MCT* Main central thrust. *Inset* shows the location of the study area (black rectangle) in the framework of the Himalayan chain. The grey shaded belt approximates the location of the Greater Himalayan Sequence. *MFT* Main frontal thrust; *MBT* Main boundary thrust

De Groot (2004). A subsequent filtration of the samples that would have precipitated enough carbonate could have led to isotopic measurement of the Dissolved Inorganic Carbon.

19.2.2 Geological Setting

The Khimti Khola, Likhu Khola and Dudhkhund Khola rivers cross the main tectonostratigraphic units of eastern Nepal Himalaya, flowing across the Greater Himalayan Sequence (GHS) and the Lesser Himalayan Sequence and crossing the Main Central Thrust Zone (MCTZ). Three of the investigated springs are located in the structurally lower GHS domain (GHS-L) (i.e. within the MCTZ), and seven are located in the upper GHS domain (GHS-U) (Fig. 19.1).

The GHS-L mainly consists of a metasedimentary sequence (mostly metapelites and minor calc-silicate rocks

and impure marbles) recording an increase in metamorphic grade upward, passing from the staurolite zone to the sillimanite zone and, locally, to anatexis (Groppo et al. 2009; Mosca et al. 2013). The GHS-U is characterized by high-grade metamorphic rocks (metapelites, metacarbonate rocks and orthogneiss), often anatectic, recording a progressive decrease in peak-pressure structurally upward (Groppo et al. 2012, 2013). Most of the analyzed springs are hosted in silicate rocks, except springs A1 and A11 that are hosted in metasedimentary rocks including impure marbles and calc-silicate levels.

19.2.3 Analytical Methods

Samples for chemical analysis were collected in pre-cleaned HDPE 250 ml bottles, without any addition of acid substances, because the same sample has to be suitable for both cations and anions determinations. Analysis were done at the Dept. Earth Sciences (Univ. Torino), using a Metrohm IC 732 Ion Chromatography System for anions quantification, and a Spectro Iris Advantage II ICP-AES for cations evaluation. Isotopic analysis were performed on five representative samples from different structural levels at ISO4 Laboratories in Turin, using a Picarro L2120-i Isotope Analyzer, with a precision of $\pm 3 \delta\text{‰}(3\sigma)$ for deuterium and $\pm 0.6 \delta\text{‰}(3\sigma)$ for ^{18}O . So far, none of the samples was submitted to DIC isotope analysis for the evaluation of $\delta^{13}\text{C}$; only sample A1 is rich enough in DIC to ensure the necessary amount of carbonate suitable for the determination.

19.3 Results

19.3.1 Geochemical Features

The analyzed springs are characterized by low discharge temperature varying between 3 and 16 °C, with a negative correlation between temperature and altitude (Table 19.1). They are characterized by a very low salinity (TDS < 150 mg/L) and a correspondent very low conductivity (<200 $\mu\text{S}/\text{cm}$). The pH varies between 6.5 and 7.3 and the samples are Ca–Mg– HCO_3^- in composition (Fig. 19.2a). No significant compositional variations are observed between the GHS-L and the GHS-U springs; the springs hosted in metacarbonate rocks show the highest TDS.

Overall the characteristics of the analyzed cold-springs are coherent with those described by previous authors in other areas of central Nepal Himalaya (e.g. cold-springs of

the Marsyandi Valley: Evans et al. 2001; Becker et al. 2008). Cold-springs composition is significantly different from that of the well-known hot-springs located along the MCT, which are typically Na–Cl to Na–Ca–Cl type waters with high total dissolved solids (TDS up to 8,500 mg/L), vary in temperature between 20 and 60 °C and have a pH in the range 5.5–7 (e.g. Evans et al. 2004; Becker et al. 2008; Perrier et al. 2009).

19.3.2 Isotopical Features

The very low total dissolved solids of the measured samples hampered the possibility of analyzing their carbon isotopic composition. Five of the water samples were submitted to isotopic determination to measure hydrogen and oxygen values. These are typical of meteoric waters and show a very good correlation with the Global Meteoric Water Line (GMWL) of precipitation (IAEA 1970, 2005), lying directly upon or very near the GMWL (Fig. 19.2b). A difference is clearly visible between samples collected at minor altitude (A1 and A2) and those collected at higher altitude. The close correlation suggests the absence of any evaporation process prior of the infiltration of rain runoff, or exchange reactions between the infiltrated water and the host rocks. Topography and altimetry indicate that a short distance could be traveled through the hosting geological formation between recharge area and spring location; therefore, the short residence time, combined with the low water temperature, prevented reactions with silicates.

19.4 Conclusions and Further Studies

Our preliminary data obtained from Himalayan high-altitude cold-springs show waters with low salinity contents and an isotopic signature that clearly indicates a provenience from meteoric rain-fall. Low temperature of the waters, as well as the low content in chloride and other ions, suggest that these springs are unrelated to geothermal activity. Overall, chemical and isotopic data are in good agreement with the few data on Himalayan cold-springs already available in the literature.

Since the isotopic determinations are related to a single sampling campaign, they do not allow further hypothesis about water circulation and seasonal change, or variations in the hydrological cycle. However, these are amongst the first δD and $\delta^{18}\text{O}$ data for high-altitude cold-springs from remote areas of eastern Nepal Himalaya. New sampling

Table 19.1 Location, field observations

Sample	Altitude (m a.s.l.)	GPS coordinates	Host rocks	Estimated discharge rate (l/sec) and field observations	T °C	pH	Conductivity ($\mu\text{S cm}^{-1}$)	TDS (mg/l)	Na ⁺ (mg/l)	K ⁺ (mg/l)	Ca ⁺⁺ (mg/l)	Mg ⁺⁺ (mg/l)	NH ⁺⁺ (mg/l)	F ⁻ (mg/l)
A1	1805	N27°36'27.0" E86°17'47.4"	Wm+ CM Slladic schist and Phl + Wm imoure	10–20 l/sec; several discharge points in the alluvial sediments	16.1	73	172	134.4	0.83	1.57	12.70	4.50		0.02
A2	1960	N27°38'32.9" E86°19'08.0"	Fine-grained two- micas Grl-bearing gneiss	<1 l/sec and discontinuous; few discharge points at the base of an alluvial fan	15.0	71	28	25.15	1.44	0.61	1.71	0.42	0.08	
A3	3930	N27°42'57.0" E86°23'4.8"	Two-micas Grl- and Ky- bearing gneiss	<0.1 l/sec, single discharge point in the alluvial sediments	60	68	18	14.51	0.68	0.92	0.85	0.31		
A4	4510	N27°43'57.3" E86°25'21.6"	Bt + Grt + Sil anatectic gneiss	0.1–0.2 l/sec, few discharge points from the rock outcrop	30	69	21	17.11	0.5	0.32	2.22	0.29		0.01
A5	4370	N27°43'54.9" E86°26'15.4"	Bt + Grt + Sil anatectic gneiss	2 l/sec, few discharge points at the base of an alluvial fan	51	72	7	8.27	0.14	0.3	0.81	0.28		0.00
A6	4140	N27°45'48.0" E86°28'03.4"	Fine-grained Bt gneiss with Sil + Qtz nodules	1 l/sec; single discharge point in the alluvial sediments	56	7	15	14.39	0.39	0.44	1.80	0.32		0.01
A7	4380	N27°45'11.0" E86°30'37.5"	Bt + Grt + Sil anatectic gneiss	0.1–0.2 l/sec; single discharge point from Vie	36	7	25	23.66	0.24	0.39	2.74	0.46		0.01
A8	3090	N27°36'43.2" E86°20'47.8"	Two-micas Grl- bearing quartzitic mica schist	0.1–0.2 l/sec; single discharge point from Vie colluvial sediments	92	68	8	10.29	0.04	0.47	0.60	0.42		
A9	3700	N27°38'00.1" E86°32'04.6"	Bt + Grt + Sil anatectic augen- gneiss	0.1–0.2 l/sec; single discharge point from Vie colluvial sediments	69	69	16	15.97	0.64	0.57	1.28	0.46	0.13	0.00
A10	3870	N27°39'23.1" E86°33'04.7"	Bt + Grt + Sil anatectic augen- gneiss	0.1–0.3 l/sec, single discharge point in the alluvial	79	63	15	14.28	0.55	0.68	1.40	0.42		
A11	4465	N27°41'44.6" E86°35'41.9"	Calc-silicate granofels and imoure marble	50–100 l/sec; few discharge points from the rock outcrop	3.6	6.5	55	43.06	0.49	0.63	6.29	0.33		0.02

(continued)

Table 19.1 (continued)

Sample	Altitude (m a.s.l.)	GPS coordinates	Host rocks	Estimated discharge rate (l/sec) and field observations	Cl ⁻ (mg/l)	HCO ³⁻ (mg/l)	CO ³⁻ (mg/l)	NO ²⁻ (mg/l)	SO ₄ ²⁻ (mg/l)	PO ₄ ³⁻ (mg/l)	NO ₃ ⁻ (mg/l)	$\delta^{18}\text{O}$ (‰ VSMOW)	δD (‰ VSMOW)
A1	1805	N27°36'27.0" E86°17'47.4"	Wm + CM Silladic schist and Phl + Wm imoure	10–20 l/sec; several discharge points in the alluvial sediments	0.82	111.1	0.00	0.22	0.87	0.00	1.84	-8.74	-60.01
A2	1960	N27°38'32.9" E86°19'08.0"	Fine-grained two- micas Grl-bearing gneiss	<1 l/sec and discontinuous; few discharge points at the base of an alluvial tar	0.21	19.53	0.00	0.00	0.42	0.00	0.73	-9.13	-61.78
A3	3930	N27°42'57.0" E86°23'4.8"	Two-micas Grl- and Ky- bearing gneiss	<0.1 l/sec, single discharge point in the alluvial sediments	0.97	6.10	0.00	0.00	0.21	0.17	4.30		
A4	4510	N27°43'57.3" E86°25'21.6"	Bt + Grt + Sil anatectic gneiss	0.1–0.2 l/sec, few discharge points from the rock outcrop	0.10	9.75	0.00	0.00	3.40	0.00	0.51	-14.40	-102.46
A5	4370	N27°43'54.9" E86°26'15.4"	Bt + Grt + Sii anatectic gneiss	2 l/sec, few discharge points at the base of an alluvial fan	0.09	4.88	0.00	0.00	1.19	0.00	0.58		
A6	4140	N27°45'48.0" E86°28'03.4"	Fine-grained Bt gneiss with Sil + Qtz nodules	1 l/sec; single discharge point in the alluvial sediments	0.23	9.76	0.00	0.01	0.90	0.00	0.52		
A7	4380	N27°45'11.0" E86°30'37.5"	Bt + Grt + Sil anatectic gneiss	0.1–0.2 l/sec; single discharge point from Vie	0.09	17.09	0.00	0.00	2.30	0.00	0.35		
A8	3090	N27°36'43.2" E86°20'47.8"	Two-micas Grt- bearing quartzitic mica schist	0.1–0.2 l/sec; single discharge point from Vie colluvial sediments	0.28	7.32	0.00	0.00	0.15	0.00	1.00		
A9	3700	N27°38'00.1" E86°32'04.6"	Bt + Grt + 311 anatectic augen-crneiss	0.1–0.2 l/sec; single discharge point from Vie colluvial sediments	0.20	12.20	0.00	0.00	0.13	0.04	0.29		
A10	3870	N27°39'23.1" E86°33'04.7"	Bt + Grt + Sil anatectic augen-	0.1–0.3 l/sec, single discharge point in the alluvial	0.36	9.76	0.00	0.00	0.89	0.00	0.22		-9327
A11	4465	N27°41'44.6" E86°35'41.9"	Calc-silicate granofels and imoure marble	50–100 l/sec; few discharge points from the rock outcrop	0.16	29.29	0.00	0.00	5.40	0.00	0.45	-15.52	-113.24

Stable Isotope, and chemical data for the cold-spring of the Numbur and Dudh Khund area

Fig. 19.2 **a** Piper diagram of the investigated water samples, showing their Ca–Mg–HCO₃ composition. **b** Projection of the isotopic data of the studied Himalayan cold-spring along with a projection of the Global Meteoric Water Line (in green). The studied samples are in

good agreement (within the instrumental uncertainty) with rain waters with no (or very few) evaporation and/or exchange with the mineralogical assembly of the host rock. In both the diagrams, orange symbols GHS-L springs; blue symbols GHS-U springs

campaigns, planned for the next future, will increase the sampling density of both cold- and hot- springs thus allowing to achieve a better understanding of the hydro- logical cycle in the area.

References

- Becker JA, Bickle MJ, Galy A, Holland TJB (2008) Himalayan metamorphic CO₂ fluxes: quantitative constraints from hydrothermal springs. *Earth Planet Sci Lett* 265:616–629
- De Groot PA (2004) Handbook of stable isotope analytical techniques. Elsevier, Amsterdam
- Evans KA (2011) Metamorphic carbon fluxes: how much and how fast? *Geology* 39:95–96
- Evans MJ, Derry LA, Anderson SP, France-Lanord C (2001) Hydrothermal source of radiogenic Sr to Himalayan rivers. *Geology* 29:803–806
- Evans MJ, Derry LA, France-Lanord C (2004) Geothermal fluxes of alkalinity in the Narayani river system of central Nepal. *Geochim Geophys Geosyst* 5:Q08011
- Groppo C, Rolfo F, Lombardo B (2009) P–T evolution across the main central thrust zone (Eastern Nepal): hidden discontinuities revealed by petrology. *J Petrol* 50:1149–1180

- Groppo C, Rolfo F, Indares A (2012) Partial melting in the Higher Himalayan Crystallines of Eastern Nepal: the effect of decompression and implications for the “channel flow” model. *J Petrol* 53:1057–1088
- Groppo C, Rolfo F, Mosca P (2013) The cordierite-bearing anatectic rocks of the Higher Himalayan Crystallines (eastern Nepal): low-pressure anatexis, melt-productivity, melt loss and the preservation of cordierite. *J Metamorph Geol* 31:187–204
- IAEA (1970) Technical report IAEA-116, Interpretation of environmental isotope data in hydrology. International Atomic Energy Agency, Vienna
- IAEA (2005) Isotopes in the water cycle: past, present and future of a developing science. International Atomic Energy Agency, Vienna
- Mosca P, Groppo C, Rolfo F (2013) Main geological features of the Rolwaling-Khumbu Himal between the Khimti Khola and Dudh Khosi valleys (eastern-central Nepal Himalaya). *Rend Online Soc Geol It* 29:112–115
- Perrier F, Richon P et al (2009) A direct evidence for high carbon dioxide and radon-222 discharge in Central Nepal. *Earth Planet Sci Lett* 278:198–207
- Rolfo F, Groppo C, Mosca P, Ferrando S, Costa E, Kaphle KP (2014) Metamorphic CO₂ degassing in the active Himalayan orogen: exploring the influence of orogenic activity on the long-term global climate changes

Author Query Form

Book ID : **326568_1_En**
Chapter No.: **19**

Please ensure you fill out your response to the queries raised below and return this form along with your corrections

Dear Author

During the process of typesetting your chapter, the following queries have arisen. Please check your typeset proof carefully against the queries listed below and mark the necessary changes either directly on the proof/online grid or in the 'Author's response' area provided below

Query Refs.	Details Required	Author's Response
AQ1	Please provide complete details of the reference 'Rolfo et al. (2014)'.	

MARKED PROOF

Please correct and return this set

Please use the proof correction marks shown below for all alterations and corrections. If you wish to return your proof by fax you should ensure that all amendments are written clearly in dark ink and are made well within the page margins.

<i>Instruction to printer</i>	<i>Textual mark</i>	<i>Marginal mark</i>
Leave unchanged	... under matter to remain	Ⓟ
Insert in text the matter indicated in the margin	⋏	New matter followed by ⋏ or ⋏ [Ⓢ]
Delete	/ through single character, rule or underline or ⌞ through all characters to be deleted	Ⓞ or Ⓞ [Ⓢ]
Substitute character or substitute part of one or more word(s)	/ through letter or ⌞ through characters	new character / or new characters /
Change to italics	— under matter to be changed	↵
Change to capitals	≡ under matter to be changed	≡
Change to small capitals	≡ under matter to be changed	≡
Change to bold type	~ under matter to be changed	~
Change to bold italic	≈ under matter to be changed	≈
Change to lower case	Encircle matter to be changed	≡
Change italic to upright type	(As above)	⋏
Change bold to non-bold type	(As above)	⋏
Insert 'superior' character	/ through character or ⋏ where required	Y or Y under character e.g. Y or Y
Insert 'inferior' character	(As above)	⋏ over character e.g. ⋏
Insert full stop	(As above)	⊙
Insert comma	(As above)	,
Insert single quotation marks	(As above)	Y or Y and/or Y or Y
Insert double quotation marks	(As above)	Y or Y and/or Y or Y
Insert hyphen	(As above)	⌞
Start new paragraph	⌞	⌞
No new paragraph	⌞	⌞
Transpose	⌞	⌞
Close up	linking ○ characters	○
Insert or substitute space between characters or words	/ through character or ⋏ where required	Y
Reduce space between characters or words		↑