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# Global tephra studies: role and importance of the international tephra research group "Commission on Tephrochronology" in its first 60 years

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**Abstract.** Tephrochronology is a correlational and age-equivalent dating method whereby practitioners characterize, map, and date tephra (or volcanic ash) layers and use them stratigraphically as connecting and dating tools in the geosciences (including volcanology) and in studies of past environments and archaeology. Modern tephra studies per se began around 100 years ago (in the 1920s), but the first collective of tephrochronologists with a common purpose and nascent global outlook was not formed until 7 September 1961 in Warsaw, Poland. On that date, the inaugural "Commission on Tephrochronology" (COT) was ratified under the aegis of the International Union for Quaternary Research (INQUA). The formation of COT is attributable largely to the leadership of Kunio Kobayashi of Japan, the commission's president for its first 12 years. We were motivated to record and evaluate the function and importance of COT because tephrochronology continues to grow globally and its heritage needs to be understood, appreciated, and preserved. In addition, studies on cryptotephras, which are fine-grained glass-shard and/or crystal concentrations preserved in sediments or soils but insufficiently numerous to be visible as a layer to the naked eye, have also expanded dramatically in recent times. Therefore, in this article, we review the role and impacts of COT under the umbrella of INQUA for 53 of the last 60 years or under IAVCEI (International Association of Volcanology and Chemistry of the Earth's Interior) for 7 of the last 60 years, including since 2019. The commission also functioned under other names (abbreviated as COTS, CEV, ICCT, COTAV, SCOTAV, and INTAV; see Table 2 for definitions). As well as identifying key persons of influence, we describe the development of the commission, its leaders, and its activities, which include organizing nine specialist tephra field meetings in seven different countries. Members of the commission have participated in numerous other conferences (including specialist tephra sessions) or workshops of regional to international scale, and they have played leading roles in international projects such as INTIMATE (INTegrating Ice-core, MArine and TErrestrial records) and SMART (Synchronising Marine And ice-core Records using Tephrochronology). As well as strongly supporting early-career researchers including graduate students, the commission has generated 10 tephra-themed journal volumes and two books. It has published numerous other articles including field guidebooks, reports, and specialist internet documents/sites. Although its fortunes have ebbed as well as flowed, the commission began to prosper after 1987 when key changes in leadership occurred. COT has blossomed further, especially in the past decade or so, as an entire new cohort of specialists, including many engaged in cryptotephra studies, has emerged alongside new geoanalytical and dating techniques or protocols to become a vibrant global group today. We name 29 elected officers who have been involved with COT since 1961 as well as 15 honorary life members. After reviewing the aims of the commission, we conclude by evaluating its legacies and by documenting current and future work.



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**Dedication.** This article is dedicated to the memory of Kunio Kobayashi, who led the founding of the Commission on Tephrochronology in 1961 and helped guide its earliest years.

## 1 Introduction

In this article, we review, for the first time, the history and significance of global collaboration over the past 60 years by specialists – known as tephrochronologists – in the study of tephra (or volcanic ash) deposits undertaken via an international tephra research group known as the "Commission on Tephrochronology" (COT). We begin by defining the discipline of tephrochronology and its functioning before outlining the basis and scope of our review of COT and its role and impacts as a global organization over the past 60 years.

### 1.1 What is tephrochronology?

"Tephrochronology" is a unique geoscientific method that uses characterized volcanic ash (or tephra) deposits to connect and date geological, palaeoenvironmental, or archaeological sequences or events, and to transfer and apply relative or numerical ages to them where such ages have been attained for the tephras (Table 1; Thórarinsson, 1970; Lowe, 2011a). This method of transferring ages from one site to another using dated tephra deposits common to each is known as age-equivalent dating (Lowe and Alloway, 2015). The age transfer at the heart of tephrochronology is well founded because tephras are erupted and deposited essentially instantaneously (in terms of the geological timescale), forming an isochron (or chronostratigraphic horizon or time plane), which is a thin layer or surface essentially of the same age everywhere it occurs: most volcanic eruption events, especially very explosive, tephra-generating phases, typically last for only hours or days, some perhaps weeks or months (Lowe, 2011a). Examples of geological isochrons other than tephra layers include magnetic polarity reversal horizons and tektite deposits (Pillans, 2013). Even where a tephra layer is of uncertain or unknown age, it provides a correlatable datum as it still represents an isochron that allows the sequence in which it is found – on land, sea, or ice – to be correlated with other sequences where the same tephra occurs. Hence, sedimentary deposits or paleosols with their palaeoarchival evidence are able to be positioned very precisely, or they may be synchronized, on a common timescale using identified tephra layers as stratigraphically fixed tie points (Lowe, 2011a).

Undertaking tephrochronology relies on the principles of stratigraphy and on characterizing or "fingerprinting" tephra layers to enable them to be connected spatially (i.e. correlated) using both physical properties evident in an outcrop in the field (e.g. Cas and Wright, 1987, pp. 477–478) and those obtained from laboratory analysis, including mineralogical examination by optical microscopy or geochemical analysis of glass shards or crystals using the electron microprobe and other techniques (Alloway et al., 2013; Lowe and Alloway, 2015). Numerical ages for a tephra layer may be obtained using (i) radiometric methods such as radiocarbon, fission-track dating (zircon, glass), U-series including (U-Th)/He, Ar/Ar, or luminescence; (ii) incremental dating including dendrochronology, varved sediments, or layering in ice cores; (iii) age-equivalent methods such as magnetopolarity, astronomical (orbital) tuning, or correlation with marine oxygen isotope stages; (iv) age modelling including Bayesian flexible depositional modelling and wiggle-match dating; and (v) historical records or observations (e.g. Colman et al., 1987; Lowe and Alloway, 2015; Hopkins et al., 2021a). A range of visual and statistical methods can be used to facilitate correlation that may also include some measure of probability (e.g. Pouget et al., 2014; Lowe et al., 2017a; Petrelli et al., 2017; Bolton et al., 2020; Uslular et al., 2022).

In using the term tephrochronology, it should be appreciated that the original final "a" of the root word téphra (Table 1) is normally replaced with the connecting vowel "o" in deriving compound words in English based on Greek root words (Froggatt and Lowe, 1990; Lowe and Hunt, 2001).

### 1.2 Application of tephrochronology

Now recognized globally as one of the most versatile methods available to geoscientists, palaeoenvironmental scientists, and archaeologists and palaeoanthropologists, tephrochronology is potentially applicable over timescales spanning years to millions of years (Abbott et al., 2020a). Moreover, the method has the potential to correlate sequences over distances ranging from metres to thousands of kilometres as well as the capability to link and date proximal, metre-thick deposits to diminutive distal layers comprising barely a handful of glass shards that have no visible expression (i.e. cryptotephras) (Hunt, 1999b; Abbott et al., 2020a). Applications of tephrochronology, chiefly for the Quaternary period, are equally varied and are becoming increasingly important in wide-ranging geological, geochronological, palaeoenvironmental, archaeological, and volcanological studies (Lowe, 2011a; Alloway et al., 2013; Cashman and Sparks, 2013; Lane and Woodward, 2022). Correlating dispersed tephra deposits, especially where well dated, back to their volcanic sources allows tephrochronological studies to provide information on the eruption frequency (i.e. eruption history) and geochemical evolution (petrogenesis) of volcanic regions and individual volcanoes (e.g. Thordarson and Larsen, 2007; Cashman and Sparks, 2013; Abbott et al., 2020a), as well as informing volcanic hazard modelling relating to, for example, aviation hazards (e.g. Prata and Rose, 2015; Bourne et al., 2016), impacts on human health (e.g. Newnham et al., 2010; Baxter and Horwell, 2015), and understanding volcano–climate interactions (e.g. Robock, 2015; Cooper et al., 2018; Marshall et al., 2022).

**Table 1.** Tephra-related nomenclature*.

| Term | Definition |
|---|---|
| Tephra (sensu lato) | Explosively erupted, pyroclastic products of a volcanic eruption encompassing all grain sizes (i.e. ash, lapilli, and blocks/bombs) and compositions irrespective of emplacement mechanism (from the Greek τέφρα (téphra), meaning "ash" or "ashes"). |
| Cryptotephra | Explosively erupted, ash-sized glass-shard and/or crystal concentration preserved in sediments or soils/paleosols but insufficiently numerous or too fine to be visible as a layer to the naked eye (from the Greek κρυπτός (kryptós), meaning "hidden" or "secret"). |
| Tephrochronology (sensu stricto) | Use of primary tephra/cryptotephra deposits as isochrons to connect and synchronize depositional sequences, or soils/paleosols, and to transfer relative or numerical ages to them using lithostratigraphic, compositional, chronological, and other data relating to the tephras or cryptotephras. |
| Tephrochronology (sensu lato) | All aspects of tephra or cryptotephra studies and their application. |
| Tephrochronometry | Obtaining a numerical age or calendrical date for a tephra layer or cryptotephra deposit. |
| Tephrostratigraphy | Study of sequences of tephra or cryptotephra deposits (and stratigraphically associated materials), their lithologies, spatial distribution, stratigraphic relationships, and relative and numerical ages; such study involves defining, describing, characterizing, and mapping tephra/cryptotephra deposits. |

* Mainly after Lowe (2011a) and Alloway et al. (2013).

## 1.3 Defining tephras and cryptotephras

"Tephra" is a collective term comprising all of the explosively erupted, fragmental volcanic material – pyroclasts – of any grain size (e.g. ash, lapilli, and blocks or bombs), composition, or emplacement mechanism (Wright et al., 1981; Froggatt and Lowe, 1990; Cashman and Scheu, 2015). Throughout this article, the word tephra refers mainly to pyroclastic *deposits* (cf. *material*) that are predominantly unconsolidated (Schmid, 1981; Le Maitre, 2002). Pluralization as "tephras", with the appended "s", is appropriate in modern geoscientific usage of transliterations and avoids ambiguity (Froggatt and Lowe, 1990; Juvigné, 1990; Lowe, 2011a).

"Cryptotephras" are explosively erupted, ash-sized, glass-shard and/or crystal concentrations that are preserved in sediments (including ice), or soils and paleosols, but which are insufficiently numerous (too sparse or disseminated), too thin, or too fine grained to be visible as a layer to the naked eye (Hunt, 1999a; Lowe, 2011a; Lane et al., 2017a). The prefix "crypto" derives from a Greek word for "hidden" or "secret" (Table 1), conveying the hidden or concealed nature of these deposits (Lowe and Hunt, 2001).

## 1.4 Development of cryptotephra studies and the advent of the modern era

The rise of cryptotephra studies is remarkable, and they have been very influential over the past 3 decades, largely through the development of new techniques that have facilitated the discovery of numerous non-visible tephra deposits well beyond their previously known occurrences, in some cases by thousands of kilometres. In turn, such occurrences have greatly extended the geographical utility of cryptotephras as isochrons for correlating and dating historical, archaeological, palaeoclimatic/palaeoecologic, and geological events as well as for volcanological applications (see reviews by Lowe, 2008, 2011a; Davies, 2015; Ponomareva et al., 2015).

In terrestrial settings, fledgling cryptotephra studies began more than 6 decades ago: in Scandinavia, Christer Persson was the first to publish articles, in the 1960s–1970s, from his pioneering work on sparse, non-visible ash deposits preserved in peat bogs (Persson, 1966, 1971; see also Thórarinsson, 1970; Wastegård, 2005). Following this, in New Zealand, sparse glass shards – and crystals – preserved in soils/paleosols, or peat, lake, or marine sediments, were investigated from the mid-1970s to the mid-1980s by Hodder and Wilson (1976), Stewart et al. (1977, 1984), Lowe et al. (1981), Robertson and Mew (1982), Hogg and McCraw (1983), Kyle and Seward (1984), and Lowe (1986) (see also Hopkins et al., 2021a). Even earlier, however, some embryonic studies on marine sediments showed that volcanic glass shards formed "volcanic ash zones" in which the shards were sometimes described as "ill-defined layers" or as being "not concentrated in distinct layers" (Bramlette and Bradley, 1940, p. 3). Similarly, Kennett and Watkins (1970), in separating sand-size fractions from marine sediments, noted that constituent "volcanic shards... do not form megascopically distinct layers..." (p. 932). In both of these and likely many other cases, especially those reported from the 1970s onward (e.g. Ruddiman and McIntyre, 1973; Huang et al., 1975), such indistinct glass-shard concentrations would qualify nowadays as cryptotephras (see also Kennett, 1981).

Despite these early cryptotephra studies, tephrochronologists today recognize that the new discipline of "cryptotephrochronology" was propelled into the modern *systematic* era from 1990 by the publication of Andrew Dugmore's seminal UK-based paper in 1989 (Dugmore, 1989). The term cryptotephra, although introduced in 1999 as "crypto tephras" (Hunt, 1999a, p. viii), was first defined only in 2001 (Juvigné et al., 2001; Lowe and Hunt, 2001). The discipline has subsequently witnessed new or improved techniques and applications which, along with an entirely new type of researcher, have emerged to cater for the demanding, forensic-like requirements of such research (e.g. Kalliokoski et al., 2020; Krüger and van den Bogaard, 2021; Larsson et al., 2022). Initially targeting archives mainly comprising peat and lake sediment, ice cores and marine sediments soon became another important focus (e.g. Abbott and Davies, 2012; Davies et al., 2014; Abbott et al., 2018a, 2020a). Aeolian deposits including loess (e.g. Eden et al., 1992, 1996; Neall et al., 2001; Matsu'ura et al., 2012; Obreht et al., 2016), and caves and rock shelters, have also yielded cryptotephras (e.g. Lane et al., 2011; Barton et al., 2015; Bruins et al., 2019; Hirniak et al., 2020), as have stalagmites (Klaes et al., 2022). Here, we list further examples including benchmark methodological papers, regional reviews, and recent papers on long sedimentary sequences that collectively emphasize the growing importance of cryptotephrochronological research: Turney (1998), Hunt (1999b), Hall and Pilcher (2002), van den Bogaard and Schmincke (2002), Davies et al. (2004, 2014), Gehrels et al. (2008), Wastegård and Davies (2009), Swindles et al. (2011, 2019), Lawson et al. (2012), Matsu'ura et al. (2012, 2021), Wastegård and Boygle (2012), Lane et al. (2013, 2014), Riede and Thastrup (2013), Smith et al. (2013), Abbott et al. (2018a, b, 2020a), Menke et al. (2018), Wulf et al. (2018), Albert et al. (2019), Leicher et al. (2019), Jones et al. (2020), Freundt et al. (2021), Jensen et al. (2021), and Kinder et al. (2021).

### 1.5 Reviewing the Commission on Tephrochronology (COT)

The discipline of tephrochronology (and its burgeoning offspring, cryptotephrochronology), as outlined above, is growing from strength to strength. To date, however, information about COT, its leadership, its activities, and its fortunes, is scattered and sparse, and so we have assembled this review mainly because we recognized that such knowledge, especially relating to the early years, was fast fading and needed preserving and evaluating as a legacy for succeeding generations. Thus, we think that our review is timely and important. We were also motivated by the especially strong support of commission members over the past decade, growing to over ∼200 including increasing numbers of early-career researchers (ECRs), many now becoming proficient and experienced, as expressed at well-attended tephra meetings held in Kirishima, Japan (2010); Nagoya, Japan (2015); Portland, Oregon (2017); Moieciu de Sus, Romania (2018); and Dublin, Ireland (2019) (see Sect. 3). These contemporary practitioners wanted to maintain and enhance the active global collective that the commission had now become.

Although currently (and initially) known as the Commission on Tephrochronology, the tephra research group has functioned under six other names since its formation (Table 2). Moreover, the commission has been hosted at different times by one or the other of two large scientific unions: the International Union for Quaternary Research (INQUA) and the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) (see Sect. 2.2).

In undertaking the review, we drew on our own and others' experience, various papers, and snippets from conference proceedings and reports (as available) to provide a historical framework for the commission and some of its globally focussed activities (mainly conferences or workshops) since its founding in 1961. We include a variety of images to add colour and to show a range of the activities, as well as some of the people, involved in securing the accomplishments of COT.

We refer in the narrative to a number of key people and events as well as to critical progress in the development of analytical and other techniques or protocols pertaining to COT. Although we contend that the achievement of the disciplinarity of tephrochronology has arisen in part because of the development of COT, we acknowledge that multiple factors have been influential (e.g. see Paredes-Marino et al., 2022), such as discussed in a broader philosophical context by Good (2000). Wider developments in the discipline of tephrochronology and its advances are documented extensively elsewhere (e.g. Kittleman, 1979; Kennett, 1981; Thórarinsson, 1981; Westgate and Gorton, 1981; Fisher and Schmincke, 1984; Einarsson, 1986; Bitschene and Schmincke, 1990; Knox, 1993; Feibel, 1999; Sarna-Wojcicki, 2000; Shane, 2000; Turney and Lowe, 2001; Machida and Arai, 2003; Dugmore et al., 2004; Suzuki, 2007; Froese et al., 2008a; Lowe, 2008, 2011a, 2014; Dugmore and Newton, 2009; Lowe et al., 2011a, 2017a; Alloway et al., 2013; Houghton, 2015; Lowe and Alloway, 2015; Lane et al., 2017a; Abbott et al., 2020a).

Numerous geoscientists, including many in leadership roles, have been involved with the commission. We record the names of those who have held positions as elected officers or who convened conferences or workshops on behalf of the global tephra community. The contributions of various individuals to the discipline of tephrochronology, addressed in some cases in our article, have been reported in special editorials, historical articles, or obituaries (see Einarsson, 1982; Vucetich, 1982; Björnsson, 1983; Royal Geographical Society, 1983; Noe-Nygaard, 1984; Steinthórsson, 1985, 2012; Lowe, 1990a; Wilson, 2005; Self and Sparks, 2006; Tonkin and Neall, 2007; Froese et al., 2008b; Lowe et al., 2008a, 2017b, D. J. Lowe et al., 2015; Slate and Knott, 2008; Hunt, 2011; Moriwaki et al., 2011a; Suzuki et al., 2011; Benedik-

**Table 2.** Progression of names (with abbreviations) of the international tephra research group associated with INQUA[a] or IAVCEI[b].

| | |
|---|---|
| 2019–present | Commission on Tephrochronology (COT) – IAVCEI |
| 2007–2019 | International Focus Group on Tephrochronology and Volcanism (INTAV) – INQUA |
| 2003–2007 | Subcommission on Tephrochronology and Volcanism (SCOTAV) – INQUA |
| 1995–2003 | Commission on Tephrochronology and Volcanism (COTAV, COTS)[c] – INQUA |
| 1991–1995 | Commission on Tephrochronology (COT) – INQUA |
| 1987–1991 | Inter-congress Committee on Tephrochronology (ICCT) – INQUA |
| 1982–1987 | Commission on Explosive Volcanism (CEV)[d], International Association of Volcanology and Chemistry of the Earth's Interior – IAVCEI |
| 1961–1982 | Commission on Tephrochronology or Commission on Tephra (COT), International Union for Quaternary Research – INQUA |

[a] For a history of INQUA (and Quaternary science), see Neustadt (1969), Porter (1999), and Smalley (2011). [b] For a history of IAVCEI, see Cas (2019, 2022). A wider perspective on the development of international cooperation in geosciences is given by Ismail-Zadeh (2016). [c] According to Lowe (1995, 1996a), the commission from 1995 was initially the Commission on Tephra Studies (COTS). [d] COT was effectively replaced with CEV in this period (see Table 4) (CEV exists today alongside COT within IAVCEI). Note that CEV was initially called the Working Group on Explosive Volcanism (see Sect. 4.3).

tsson et al., 2012a; Alloway et al., 2013; Kile, 2013; Thomas and Lamothe, 2014; Plunkett et al., 2017; Lundqvist et al., 2019; Bunting et al., 2020; Mazei et al., 2020; Hopkins et al., 2021a; Stork-Bullock Mortuary, 2021).

## 2 Formation of COT

In this section, we describe how COT was formed largely by the substantial, far-sighted efforts of a tephra specialist from Japan, Professor Kunio Kobayashi, initially with the support of two key colleagues and the National Committee of Quaternary Research of Japan. We then describe the relationship of the commission to its two hosting organizations, INQUA and IAVCEI, over the past 60 years.

### 2.1 Forming COT in 1961

The formation of the commission was initiated at a meeting of the National Committee of Quaternary Research, Science Council of Japan, in Tokyo on 6 February 1961. Attendants at the meeting agreed that a proposal to form a commission on tephrochronology should be developed and presented at the forthcoming sixth congress of the International Union for Quaternary Research (INQUA) being held in Warsaw, Poland, in September that year. Kunio Kobayashi (Fig. 1), Sohei Kaizuka, and Masao Minato were appointed to develop the proposal (Kobayashi, 1965).

The Japanese troika prepared the proposal and, before the Warsaw congress, mailed it to those engaged in tephrochronological studies in various volcanic regions of the world and to the congress secretariat. The secretariat copied part of the proposal, along with a list of publications on tephra studies provided by the Kanto Loam Research Group of Japan, for distribution to conference participants.

**Figure 1.** Professor Kunio Kobayashi (19 February 1918–19 June 1979) – the driving force and founding president of COT. Photo taken 12 October 1978 (from Committee for Publishing of Selected Papers by Professor Kunio Kobayashi, 1990).

The pre-congress proposal to form a COT within INQUA was as follows (Kobayashi, 1965, p. 782):

> Aims of the Commission: To advance the progress to the method [i.e. to further develop the method] of tephrochronology and Quaternary researches based on tephrochronology.
>
> Means of achieving these aims: 1. Gathering and exchange of information on tephrochronological studies in various countries; 2. Report on the results of studies at the next INQUA congress.
>
> Proposed by Masao Minato (Hokkaido University), Kunio Kobayashi (Shinshu University), Sohei Kaizuka (Tokyo Metropolitan University).

At the Warsaw congress, the three proposers and others convened on 6 September 1961 to formulate a resolution to present to the General Assembly. Despite all of the preparatory work, it seems that the process was by no means plain sailing. On arrival in Warsaw, Kobayashi had scanned the list of scientists coming to the congress and discovered to his consternation that no tephra specialists were attending (other than from Japan). However, Terah ("Ted") L. Smiley, a dendrochronologist from Tucson, USA, helped Kobayashi garner support from various delegates from a wide range of disciplines (which, on reflection, may have ultimately been to Kobayashi's advantage), including Väinö Auer, a pioneering palynologist from Finland who had worked on tephras in South America from 1928 (e.g. Auer, 1965, 1974); Neville Moar, a New Zealand palynologist who was well aware of the growing importance of tephra studies in his own work (e.g. Moar, 1961); André Cailleux, a French glacial geologist; and Carl Troll, a German geographer (Kobayashi, 1962, p. 129).

The full resolution as presented to the General Assembly is recorded below (Kobayashi, 1962, p. 130):

> [A] session of the proposed Commission on Tephrochronology was held yesterday afternoon. The significance of studies on volcanic ash layers as a key [means] of correlation of events in the Quaternary was [described] by the chairman and [the] establishment of a commission to promote the international co-operation of this matter was discussed. As a result of discussion, [and] considering the significance of investigation to clarify the sequence of events in... Quaternary volcanic activities, and also considering eolian Quaternary volcanic ash layers to be useful as a key [method for] correlation of... Quaternary formations, geomorphic surfaces and so on, the following persons cited below agreed to propose the foundation of the Commission on Tephrochronology in INQUA.
>
> They ask the General Assembly to agree [to] the foundation of a new commission and appoint Prof. Kobayashi as the organizer [chair/president] of the commission. The [president] should arrange the organization of the Commission on Tephrochronology till the following congress of INQUA 1965 and report the activities of the commission after this congress.

The resolution was signed by Ernest (Ernie) H. Muller (USA), Neville T. Moar (New Zealand), Ladislav Bánesz (Czechoslovakia), Fiorenzo Mancini (Italy), Hans-Dietrich Kahlke (Germany), Pierre Bellair (France), Ted L. Smiley (USA), Torao Yoshikawa (Japan), and Shoji Horie (Japan) (Kobayashi, 1962, p. 130). The following day, on 7 September 1961, it was adopted by the General Assembly of INQUA with Kobayashi declared the commission's founding president (Kobayashi, 1962, 1965) (see Sect. 4 below).

We note here that Neustadt (1969, p. 90) referred to the commission (which was the eighth to be formed in INQUA's history) as the "Commission pour la téphrochronologie", i.e. Commission *for* rather than *on* tephrochronology. However, we prefer "on" as reported by Kobayashi (1962, 1965), and COT forms a mellifluous acronym. Also, it seems that Kobayashi was the sole officer (president) within COT from 1961 to 1969. By the start of the 1969 Paris congress, two other commissions in INQUA similarly comprised just one president, but the remaining seven commissions had either two or three officers (Neustadt, 1969).

Interestingly, prior to the Warsaw resolution, Kobayashi had received a letter of support for the commission from Sigurdur Thórarinsson, regarded by many as the founder of the science of tephrochronology (Steinthórsson, 2012), with IAVCEI awarding a medal in his honour every 4 years. Thórarinsson emphasized that the term tephrochronology rather than ash should be used in the commission's name. In his letter from 1961, Thórarinsson defined tephrochronology as "chronology based on the study of the successive deposits of fragmental volcanic products" (Thórarinsson, 1965, p. 785). This definition relates to the original sense (sensu stricto) of the term tephrochronology – essentially as proposed by Thórarinsson (1944, 1954) and as outlined in Sect. 1 and Table 1 – namely, the use of tephra layers as isochrons to connect or correlate sequences as well as to transfer relative or numerical ages to such sequences where the tephras have been identified and dated. In recent times, however, the term tephrochronology has been used more broadly as a portmanteau term to encompass all aspects of tephra studies (including correlating and dating via tephrochronology), and this wider sense (sensu lato of Lowe and Hunt, 2001) is preferable in denominating the commission. A list under the heading "Names and addresses of researchers" (Kobayashi, 1965, p. 787) seems to comprise the first (1961–1965) general membership of COT (see Sect. 4.2 for an explanation of categories of membership developed later). A total of 20 scientists representing institutions in

11 countries are recorded, with perhaps the most prominent in tephrochronology per se being Sigurdur Thórarinsson (Iceland), Väinö Auer (Finland), Herbert Straka and Josef Frechen (West Germany), James (Jim) Healy (New Zealand), Ray Wilcox (USA), and Kunio Kobayashi and Sohei Kaizuka (Japan).

### 2.2 Hosting of commission by INQUA or IAVCEI

For most of the time since 1961, the commission has been hosted under the umbrella of INQUA (Table 2); however, with the creation of the new COT in 2019, the collective is now hosted by IAVCEI, where the group was, in effect, temporarily housed between 1982 and 1987. The penultimate incarnation, INTAV, was formed in 2007 as an international focus group (IFG) within the newly formed Stratigraphy and Chronology Commission (SACCOM) of INQUA (Table 2). INTAV operated under the INTREPID projects I and II (2009–2015, "Enhancing tephrochronology as a global research tool") and then the EXTRAS project (2015–2019, "EXTending TephRAS as a global geoscientific research tool stratigraphically, spatially, analytically, and temporally within the Quaternary") (Lowe, 2013, 2015, 2018a).

Most recently, discussions at the "Tephra Hunt" meeting in Romania in 2018 led to an almost unanimous decision to form a new commission (COT) within the IAVCEI framework rather than INQUA. The rationale for change is outlined in Lowe et al. (2018), and some of the difficulties of INQUA's cumbersome structure and processes were expressed by Ashworth (2018). The main reason for switching to IAVCEI was that the global tephra community very strongly indicated that it wanted to remain part of a formal and, critically, *ongoing* global collective of tephra specialists as a *stand-alone entity*. This stand-alone status was available within IAVCEI (which, as a commission, would be a potential recipient of funding from that parent body) but not within INQUA. It would also allow for regular meetings of members at *specialist tephra conferences or workshops* rather than members taking part as specialists within conferences for other disciplines or multiple disciplines (important though such meetings are). Within INQUA, the original commissions such as COT had been replaced by subcommissions in 2003 at the Reno INQUA Congress, before being removed entirely because five much broader, over-arching commissions (including SACCOM) were formed in 2007 at the Cairns INQUA Congress. These new broad commissions adopted a project-based approach rather than relying on the small individual commissions, some of which were inactive, to initiate and undertake projects involving IFGs including INTAV. However, such focus groups had a limited shelf life, normally two inter-congress periods (i.e. 8 years) at most, after which they were to end, although INTAV managed to persist, somewhat aberrantly, for 12 years.

Another reason for change relates to the considerable efforts that were needed to justify the continuation of the INTAV focus group to INQUA. Such efforts included preparing annual reports and bidding for and reporting on the INTREPID and EXTRAS projects; reports were also required for *Quaternary Perspectives*, the INQUA newsletter (e.g. Lowe, 2013, 2015, 2018a, b). The increased burden of maintaining some version of COT within INQUA, the continual need to justify its existence annually, and the loss of a structural model within which it could exist as a coherent, ongoing group ultimately led to the decision to move to IAVCEI in 2019. Moreover, the move allows for greater stability and a more predictable workload for the executive officers.

Given the past support and long history associated with the commission's affiliation with INQUA, the decision for change was not taken lightly. It is emphasized that cooperation and involvement in quadrennial INQUA congresses are not precluded – in fact such involvement is welcomed – under the new arrangement with IAVCEI. Unfortunately, however, the rapid emergence of COVID-19 in 2020 and its commensurate impacts have severely limited planning and future activities. The next specialist tephra meeting of COT in Sicily, originally planned for 2020 or 2021, is delayed provisionally until September 2024. However, tephra symposia and other activities planned for the next IAVCEI Scientific Assembly in Rotorua, New Zealand (in late January/early February 2023), and for the next INQUA Congress in Rome, Italy (in July 2023), currently appear be going ahead.

## 3 Development of the commission through specialist conferences and other activities

Nine international specialist tephra-focussed field conferences, led by 23 convenors in total and attracting between 37 and 92 participants, have been organized in seven different countries around the globe since 1964 (Table 3). Each meeting, including some stand-out aspects, is described briefly below (Sect. 3.1 to 3.10). They have been referred to as "inter-congress" or "inter-INQUA" conferences because of their occurrence between the 4-yearly, full-congress meetings of INQUA. Three of the nine meetings have been held in Japan. In terms of the entire 60-year history, the number of meetings has doubled in the last 30 years, with six meetings taking place since 1991 (i.e. approximately every 5 years on average). The average number of participants at each meeting is 58. The field conferences are exceptionally important because they not only facilitate an opportunity for the presentation and discussion of the latest advances in tephra studies or their application but also provide exceptional insight into the geological, palaeoenvironmental, and archaeological history of a specific region encompassing the conference location (Davies and Alloway, 2006). Furthermore, Lowe et al. (2018, p. 1) noted that

> one of the joys of science, and tephrochronology and volcanic studies in particular, is the opportunity to meet like-minded colleagues and keen stu-

dents in the field where formalities and reserve seem to dissipate in the face of shared interests, friendly discussions at the outcrop, and in meeting new people and cultures whilst being graciously hosted in new countries.

Furthermore, the conferences provide opportunities and critical support (including mentoring) and inspiration for ECRs including PhD and masterate students. We also record some of the many other activities undertaken by members of COT in addition to the specialist tephra meetings (Sect. 3.11).

### 3.1 Tokyo, Japan, 1964

The first stand-alone specialist tephra meeting of COT took place in Tokyo, Japan, from 26 to 29 November 1964. Including field excursions to see Asama volcano and sites in Tokyo (Ikuta, Chitose, and Todoroki) (Fig. 2), the meeting attracted 50 participants, with 7 from beyond Japan, including Sigurdur Thórarinsson (Iceland) and dendrochronologist Paul E. Damon (USA) as well as Hiroshi Machida (Japan), who was attending his first COT meeting and, as of December 2021, appears to be COT's longest standing member (57 years). Seven scientific presentations were made (Neustadt, 1969).

**Figure 2.** Some of the participants on a field trip at Ikuta (an important area for Quaternary studies in Japan) during the first COT meeting in Tokyo, November 1964 (from Suzuki et al., 2011, p. 8). We include this figure, despite its limitations, because it is the only known photograph available from the first meeting.

### 3.2 Significant change after the INQUA Congress, Christchurch, New Zealand, 1973

At the 1964 Tokyo COT meeting, the decision was made to develop and publish a world bibliography of Quaternary tephrochronology (Westgate, 1974). The agreement was reinforced at the 1965 INQUA Congress in late August–early September at Boulder, USA, at a COT session that included representatives from institutions in 10 counties (Neustadt, 1969). Kunio Kobayashi and Roald ("Fryx") Fryxell handled the project initially, and John Westgate then took over upon his election as secretary of COT at the INQUA Congress in Paris in 1969. Westgate first became involved with COT at the 1965 INQUA Congress in Boulder and has, thus, been a member for 56 years as of December 2021. An ambitious deadline for completing the book's compilation was set for December 1971 (Steen-McIntyre, 1971). Substantial grants to COT provided by INQUA and other funders in the early 1970s enabled the volume, entitled *World Bibliography and Index of Quaternary Tephrochronology*, to be published by Westgate and Gold (1974), 10 years after it was first mooted (Kaizuka, 1974).

Amongst a treasure trove of wide-ranging information, the volume contains an update by Thórarinsson (1974) on the term tephra 20 and 30 years on respectively from the definitions he wrote in 1954 and 1944. In 1973, Thórarinsson, an influential "formal member" of COT at the time (later an honorary president of the commission from 1977 to 1982), was successfully persuaded at the 1973 INQUA Congress in Christchurch, New Zealand, that the term tephra be broadened to include unconsolidated pyroclastic flow (or density current) deposits (i.e. non-welded ignimbrites) as well as "airborne" fall deposits (Cole et al., 1972; Howorth, 1975; Westgate and Fulton, 1975; Thórarinsson, 1981). Although endorsed by COT, this amplification was considered by some to have ruined the use of the word tephra (sensu stricto), and there are still tephrochronologists who do not use the wider meaning (sensu lato) of the word (Vince Neall, personal communication, 2017, 2021). Even though Thórarinsson's (1954) definition did not specifically exclude flow deposits, Neall (1972, p. 510) argued that, as pyroclastic flow deposits "flow from a crater during an eruption", these deposits should not be considered tephra and, hence, should be classified separately as "flow deposits". Moreover, the original meaning of tephra was retained by Crandell and Mullineaux (1978) and Crandell et al. (1979), for example, because this narrower meaning was better suited to their volcanic hazard analyses (Vince Neall, personal communication, 2017). Similarly, Gage (1977, p. 11) rued that the "extension of meaning seems rather to detract from the value and clarity of the term".

Nevertheless, by 1973–1974, the term tephra (sensu lato) (Table 1) was no longer restricted to fall deposits, as it

**Table 3.** List of nine international tephra-centred field meetings of the commission and outputs*.

| | |
|---|---|
| 2018 | Tephra Hunt in Transylvania, Moieciu de Sus, Romania (24 June–1 July; 92 participants)[a]<br>Convenors: Daniel Veres and Ulrich Hambach |
| 2010 | Active Tephra, Kyushu, Kirishima, Japan (9–17 May; 76 participants)[b]<br>Convenors: Takaaki Fukuoka, Hiroshi Moriwaki, and Takehiko Suzuki |
| 2005 | Tephra Rush, Yukon Territory, Dawson City, Canada (31 July–8 August; 41 participants)[c]<br>Convenors: Duane Froese and John Westgate (with Brent Alloway) |
| 1998 | Tephrochronology and Co-existence of Humans and Volcanoes (Inter-INQUA and Inter-UISPP), Brives-Charensac (Haute-Loire), France (24 August–1 September; 53 participants)[d]<br>Convenors: Étienne Juvigné and Jean-Paul Raynal |
| 1994 | Tephrochronology–Loess studies–Paleopedology, Hamilton, New Zealand (7–17 February; 62 participants)[e]<br>Convenor: David J. Lowe |
| 1993 | Climatic Impact of Explosive Volcanism (PAGES/INQUA-COT Workshop), Meiji University, Chiyoda-ku, Tokyo, Japan (1–5 December; 37 participants)[f]<br>Convenors: Hiroshi Machida and James (Jim) Begét |
| 1990 | Mammoth Hot Springs, Yellowstone National Park, USA (17–26 June; 53 participants)[g]<br>Convenors: John Westgate, Nancy Naeser, and Bill Hackett |
| 1980 | Tephra Studies as a Tool in Quaternary Research, Laugarvatn (and Reykjavík), Iceland (18–29 June; 60 participants)[h]<br>Convenors: Stephen Sparks, Stephen Self, and Guðrún Larsen (with Sigurdur Thórarinsson) |
| 1964 | Tephra Field Meeting of COT (inaugural meeting), Tokyo, Japan (26–29 November; 50 participants)<br>Convenors: Kunio Kobayashi, Sohei Kaizuka, and Takeshi Matsui |

* Special tephra-focussed volumes/issues arising from these meetings as outputs are as follows: [a] Abbott et al. (2020b); [b] Lowe et al. (2011b); [c] Froese et al. (2008c); [d] Juvigné and Raynal (2001b); [e] Lowe (1996c); [f] Begét et al. (1996); [g] Westgate et al. (1992b); [h] Self and Sparks (1981c). Two further substantial publications developed by the commission comprise Westgate and Gold (1974) (see Sect. 3.2) and Lane et al. (2017b), with the latter deriving from tephra symposia at the Nagoya INQUA Congress (2015). Note also the publication of three tephra-related volumes by Firth and McGuire (1999), Hunt (1999b), and Austin et al. (2014b) that arose indirectly or directly from specialist tephra or explosive-volcanism meetings in the UK.

had been recognized that ignimbrites could be partly or entirely non-welded and unconsolidated (Ross and Smith, 1961; Sparks et al., 1973; Schmid, 1981; Froggatt and Lowe, 1990). Previously, the term "ignimbrite", first used by Marshall (1932, 1935), was employed only for welded deposits (Cole et al., 1972, pp. 686–687; Freundt et al., 2000; Lowe and Pittari, 2019) which, being "mainly consolidated", are also referred to as "pyroclastic rocks" (following definitions in Schmid, 1981; Le Maitre, 2002). Furthermore, it was argued by Thórarinsson (1974), who had used the term "tephra flow" to describe a small pyroclastic flow descending slopes of Mt Lamington in an eruption in 1951 as well as for the non-welded uppermost layer of the Thórsmörk ignimbrite in Iceland (Thórarinsson, 1969), that such flow deposits were strictly "airborne" in their emplacement (e.g. as described by Sheridan, 1979; Wilson, 1985; Branney and Kokelaar, 2002; Lube et al., 2019). Finally, most agree that the term must also include co-ignimbrite ash-fall deposits (Machida and Arai, 1976; Sparks and Walker, 1977; Crandell and Mullineaux, 1978; Cas and Wright, 1987) that arise from fallout of ash-rich convective plumes formed by the buoyant detachment of a gas–ash mixture ("ash cloud"), or by elutriation, from the top of a pyroclastic flow (density current) (Bitschene and Schmincke, 1990; Brown and Andrews, 2015; Cioni et al., 2015). We note that the term "air fall" is now rarely used, with tephra fall/fallout or ash fall/fallout, if appropriate, typically employed instead (Cole et al., 1972; Schmid, 1981; Lowe and Hunt, 2001; Lowe, 2008).

### 3.3 Laugarvatn and Reykjavík, Iceland, 1980

The next specialist tephra conference, in June 1980, took place 16 years after the 1964 Tokyo meeting. Held mainly in Laugarvatn (also Reykjavík), Iceland, it was supported by the NATO Advanced Studies Institute and COT (Fig. 3; Self and Sparks, 1981a, b).

At this Iceland meeting, it is striking that Self and Sparks (1981a, p. xii), copying Thórarinsson (1974, p. xviii), defined tephra (sensu lato) as "a collective term for all airborne pyroclasts, including both air-fall and pyroclastic flow material", pointing out that "this usage complements rather than replaces terms such as ignimbrite, welded tuff, pumice, etc., that are used to designate specific types of tephra produced by distinctive types of eruption". Furthermore, as evident on the conference logo image in Fig. 3, they referred to the Commission on "Tephra", rather than "Tephrochronology", presumably because the latter term was seen to be somewhat restricted in its original sense (use of tephra lay-


**Figure 3.** (Left) Logo for the Icelandic INQUA-COT tephra meeting in June 1980 that was designed by Sue Selkirk (Arizona State University) (Self and Sparks, 1981a), depicting the distribution of the historic silicic tephra, $H_1$, erupted from Hekla in 1104 CE, with the outermost isopach being 2 mm. The isopach map is based on Thórarinsson (1970, p. 306) and Larsen and Thórarinsson (1977, p. 29), although it was originally mapped by Thórarinsson in 1939 (Steinthórsson, 2012, p. 5). (Right) Some participants in the field in Iceland during the meeting. The figure in the centre in the blue coat with the ubiquitous red hat (as noted by Noe-Nygaard, 1984) is Sigurdur Thórarinsson; alongside him are Guðrún Larsen, conference co-organizer (with woollen hat, looking down), and (Sir) Stephen Sparks (with sample bag) (photo credit: Malcolm Buck).

ers as a correlational and age-equivalent dating tool) so that potential additional volcanological interpretations and applications appeared to be downplayed. Later, the advent of the names Commission or Subcommission on Tephrochronology and Volcanism – i.e. COTAV or SCOTAV in 1995 and 2003 respectively (Table 2) – made "volcanology" an explicit function of the commission. However, as noted previously, today's more holistic usage of tephrochronology (sensu lato), encompassing all aspects of tephra studies including volcanology, now negates this argument and obviates the need to include "volcanism" in the modern commission's name (Lowe and Hunt, 2001; Lowe, 2008). (Moreover, COT, being sponsored by IAVCEI, has an obvious volcanological connection.)

## 3.4 Mammoth Hot Springs, USA, 1990

The tephra meeting in 1990 in Mammoth Hot Springs (Yellowstone National Park), Wyoming, USA, was next, and it began what might be deemed a "golden decade" in which four specialist tephra conferences were held (Table 3). The meeting in Mammoth, under the ICCT banner, comprised around 53 participants, the majority from the USA but with representatives also from Canada, Japan, New Zealand, Australia, Belgium, Tanzania, Ethiopia, and the UK (Fig. 4). Some scientists from the USSR and several other countries were unable to attend because of financial limitations or (in the case of the Soviets) a lack of flights at that tumultuous time (Lowe, 1990b).

Presentations featured a notable array of new dating techniques for tephra components such as isothermal-plateau fission-track dating (ITPFT) of glass, single-crystal laser fusion analysis using $^{40}Ar/^{39}Ar$, luminescence dating, high-precision radiocarbon ($^{14}C$) dating using liquid scintillation spectrometry, and the application of discriminant function analysis to classify and correlate tephras based on their glass-shard major-element compositions. In addition, reports from ICCT working groups were presented, including one to standardize the characterization of tephra deposits, the role of tephra in facilitating land–sea correlations, and the development of a catalogue of widespread Quaternary tephras. A total of 5 d were spent in the field (6 or 7 counting the days travelling overland to and from Mammoth): 2 in the Yellowstone Park region of the Yellowstone Plateau Volcanic Field and 3 on a post-conference tour looking mainly at Yellowstone tephra localities, Quaternary deposits, and, occasionally, soils and paleosols in northern Yellowstone National Park and the northern Bighorn Basin, Wyoming (Lowe, 1990b).

A conspicuous outcome of the Mammoth conference was the publication of the first of a number of proceedings in the journal *Quaternary International*, which was founded in 1987 and is owned by INQUA (and therefore returns a profit to the union to help fund its activities) (Catto, 2019). The Mammoth conference special issue, entitled straightforwardly as "Tephrochronology: stratigraphic applications of tephra" and comprising 27 scientific papers, was an early double-volume of the journal (Westgate et al., 1992a, b).

## 3.5 Tokyo, Japan, 1993

The Tokyo meeting in 1993, co-sponsored by the Past Global Changes (PAGES) core project of the International Geosphere–Biosphere Programme (Oldfield, 1998) and INQUA's COT, was the first to be designated as a field conference *and workshop* because it focussed on a specific theme,

**Figure 4.** (Top) Participants of the ICCT tephra meeting held in Mammoth Hot Springs, Yellowstone National Park, USA, June 1990 (photo credit: anonymous). (Bottom) Participants in the field on 4 December 1993, near Haruna volcano, northern Kanto, Japan, during the PAGES/INQUA-COT workshop on the climatic impact of explosive volcanism (photo credit: anonymous). The names of participants standing at the back (in the bottom photograph) are as follows (from left): Fusao Arai, Hiroshi Machida, Takehiko Mikami, David Pyle, Tom Simkin, Janice Lough, David J. Lowe, James Begét, Greg Zielinski, Katherine Hirschboeck, Haraldur Sigurdsson, Tsutomu Soda, Takeshi Noto, Nat Rutter, and Koji Okumura. The names of participants crouching at the front (in the bottom photograph) are as follows (from left): unknown, Makiko Watanabe, Takehiko Suzuki, Suzanne Leroy, Valerie Hall, Hiroshi Moriwaki, Takaaki Fukuoka, Sumiko Kubo, Mika Kohno, Tatsuo Sweda, Kunihiko Endo, and Shinji Nagaoka.

namely the impact of volcanism on climate. As well as spending time in the field (Fig. 4) and on oral presentations, the 37 participants (representing institutions in six countries) were, therefore, involved in breakout sessions in four ad hoc working groups:

- modelling studies, ice cores, frozen ground, historic, and non-biological records;
- tree rings, palynology, and corals (biological records);
- volcanology and climate components;
- tephrochronology.

Their task was to answer a series of topical questions and to synthesize ideas and data. A final discussion session led to a series of recommendations that were published in a detailed report by Begét et al. (1996).

### 3.6 Hamilton, New Zealand, 1994

The meeting in Hamilton, on New Zealand's North Island, in February 1994, in addition to being the first event in the Southern Hemisphere, was noteworthy because it was the first meeting to be held under the INQUA banner that involved three commissions: tephrochronology, loess studies, and palaeopedology. The conference included a special symposium, the "C.G. Vucetich Symposium on Tephrostratigraphy and Tephrochronology in New Zealand". The 62 participants (including 12 students) from institutions in 12 countries (Fig. 5) spent 2 d in the field during the conference, and a group of 35 took part in the 5 d post-conference North Island field trip (Lowe, 1994b). Along with the field guides, the proceedings took up three slender but contiguous volumes of *Quaternary International* and comprised 27 scientific papers (Lowe, 1996b, c).


**Figure 5.** **(a)** Participants in the integrative triple-discipline (tephra–loess–paleosols) meeting at the University of Waikato, Hamilton, New Zealand, photographed on 8 February 1994 (photo credit: Ross Clayton; University of Waikato). The names of the participants standing at the back are as follows (from left): Takehiko Suzuki, Hiroshi Moriwaki, Sue Donoghue, Brent Alloway, John Westgate, Dennis Eden, Amanjit Sandhu, Yoshitaka Nagatomo, Keiji Takemura, Liping Zhou, Akira Hayashida, Étienne Juvigné, unknown, Jun'ichi Kimura, John Bruce, James Begét, and Kotaro Yamagata. The names of the participants standing are as follows (from left): Roma Lane, David Manning, John Hunt, Shane Cronin, Peter Almond, Alan Palmer, Takuo Yokoyama, Yoshinaga Shuichiro, Gordon Curry, Ken Verosub, Colin Vucetich, Margaret Vucetich, Carolyn Olson, Michael Singer, Takashi Sase, unknown, Richard Hay, and Peter Kamp. The names of the seated participants are as follows (from left): Hiroshi Machida, Jiaqi Liu, Carol Smith, Alan Hull, Colin Wilson, Milan Pavich, Brad Pillans, Glenn Berger, Liddy Bakker, David J. Lowe, Phil Tonkin, Kerry Stevens, Bernd Strieweski, Graham Shepherd, John Catt, and Janet Slate. The names of the crouching participants are as follows (from left): Benny Theng, Arno Kleber, Jim Dahm, Roger Briggs, Peter Hodder, Tim Naish, Michael Green, Mike Vennard, Denis-Didier Rousseau, and Andrew Hammond. **(b)** The front page of a flyer prepared prior to the meeting in New Zealand. **(c)** Brad Pillans exposing buried soil horizons (paleosols) formed on early-Holocene, Taupo volcano-derived rhyolitic tephras overlying steeply dipping reworked Oruanui eruptive material deposited into a temporary lake, Lake Taupo forest area, central North Island, on the first day of the post-conference field trip (13 February, stop 7; Wilson, 1994) (photo credit: David J. Lowe). **(d)** Colin Wilson explaining the stratigraphy of mid-Holocene Taupo-derived eruptive material ($\sim$ 5400–4500 cal BP) with intervening soil horizons near southern Lake Taupo (13 February, stop 11; Wilson, 1994) (photo credit: David J. Lowe).

### 3.7 Brives-Charensac, France, 1998

The meeting held in Brives-Charensac in the Haute-Loire region of southern France from 24 to 29 August 1998, with 53 participants from institutions in 11 countries, successfully brought together tephrochronology and volcanism (as represented by COT) and their relationship to humans in antiquity (Fig. 6). The latter aspect was represented by Commission 31, "Humans and Active Volcanoes during History and Prehistory", of the International Union of Prehistoric and Protohistoric Sciences (UISPP) (Table 3).

By this time, a logo for the commission had been developed by Paul van den Bogaard (Fig. 6), possibly in anticipa-


**Figure 6.** (Top) Participants of the tephra meeting held in Brives-Charensac, France, in August 1998 (photo credit: Jean-Paul Raynal). (Bottom left) Part of the cover page for the programme/abstracts volume of the meeting: the COT logo – a three-armed bubble-junction (cuspate) glass shard with an electron probe (or laser) beam spot on it – was designed by Paul van den Bogaard (Germany). (Bottom right) After COT became INTAV in 2007, cartographer Betty-Ann Kamp (University of Waikato) updated the logo in 2008, as shown here.

tion of the tephra-based field trip to the Eifel Volcanic Field undertaken prior to the Berlin INQUA Congress held in August 1995 (Lowe, 1995). The Brives-Charensac conference was followed by a 3 d post-conference field trip across the Massif Central volcanic fields. Although it had been originally planned that the conference proceedings would appear in the journal *Quaternaire*, the large number of papers accepted, 27 in total, rendered that option impractical. Remarkably, a new journal, *Les Dossiers de l'Archaéo-Logis*, was established in which all of the papers were eventually published (Juvigné and Raynal, 2001a, b).

### 3.8 Dawson City, Canada, 2005

Seven years passed before the spectacular 2005 "Tephra Rush" meeting, now under the banner of SCOTAV, was held (from 31 July to 8 August) mainly in Dawson City, Yukon Territory, Canada (Fig. 7; Alloway et al., 2005; Davies and Alloway, 2006). The meeting, comprising 41 participants from institutions in 11 countries (Table 3), began with an evening public lecture in Whitehorse by volcanologist and author Grant Heiken, thereby helping to enhance public dissemination of tephra-based research (one of the aims of the commission; see Sect. 5.1 below). Heiken explored the different human perceptions of volcanoes and the risks of living in the shadow of a volcano. A second public lecture was given during the conference in Dawson by Paul Matheus on the topic of Beringian mammals.

A 1 d field trip en route from Whitehorse to Dawson took place on 1 August 2005. It included inspection of the 833–850 CE White River Ash (eastern lobe) (Fig. 7). The eruption of this tephra was coincident with the transition in southern Yukon from atlatl and throwing-dart technology to the adoption of the bow and arrow, which were likely present a few hundred years earlier in southern Alaska. Possibly a proto-Athapaskan population inhabiting the region was strongly affected by the ecological impacts of the volcanic eruption and migrated, at least temporarily, from the thick tephra-fall region to encounter this technology (Davies and Alloway, 2006). Diminutive forms of the same White River Ash were recognized by Jensen et al. (2014) as a cryptotephra in Greenland and northern Europe (where it is dated 846–848 CE) – the first record of the "transatlantic distribution" of tephra. Two days were spent in the Klondike goldfields during the conference itself (Davies and Alloway, 2006).

The subsequent special issue of *Quaternary International*, edited by Froese et al. (2008c), comprised 20 scientific articles based on presentations at Dawson as well as from a special session of the annual Geological Society of America conference (held in Salt Lake City in October 2005) entitled "Advances and Applications of Tephrochronology and Tephrostratigraphy: in Honor of Andrei M. Sarna-Wojcicki". The special issue by Froese et al. (2008c) was the first by the commission to specifically honour in its title two of the biggest names in tephrochronology, John Westgate and Andrei Sarna-Wojcicki (Froese et al., 2008b; Slate and Knott, 2008).

### 3.9 Kirishima City, Japan, 2010

In 2010, the commission returned to Japan where a meeting was held in Kirishima City in southern Kyushu from 9 to 17 May 2010, this time under the INTAV banner. One reason for the meeting to be hosted in Japan was to expose the emerging cohort of cryptotephra specialists (who tended to work only on sparse shards from mainly distal or ultra-distal locations) to proximal pyroclastic and volcanic deposits as a way of broadening their experience and deepening understanding. The conference was held during a lull in the 2010 eruptions of Eyjafjallajökull in Iceland, with the volcano's on-and-off behaviour (Gudmundsson et al., 2010; Davies et al., 2010) creating opportunities for considerable press interest in the meeting (including local TV coverage of a special public session on the Icelandic eruptions and impacts, which featured presentations by Chris Hayward, Siwan Davies, and Thor Thordarson) and considerable headaches with respect to travel arrangements (Holt and Lowe, 2010). Of the 76 participants in attendance from institutions in 12 countries, a substantial proportion (25) comprised students. At the start of the conference, two consecutive public lectures to an audience of around 800 in Kirishima's City Hall were given by David J. Lowe ("Connecting with our past: using tephras and archaeology to date the Polynesian settlement of Aotearoa/New Zealand"), with Lowe's talk being translated into Japanese as he spoke, and Hiroshi Machida ("Widespread tephras originating from Kagoshima occurring in northeast Asia and adjacent seas"). In addition, the mayor of Kirishima City, Shuji Maeda, graciously invited the entire conference group to his personal residence for a spectacular banquet early in the conference which included the use of dining "rooms" in caves cut into exposures of Ito ignimbrite (see below) at the property.

New work on the tephrostratigraphic record of ice cores was presented as well as new protocols involving electron probe microanalysis (EPMA) and laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analysis of glass shards considerably smaller than previously attainable ($\sim 5$ and $\sim 10\,\mu m$ in diameter respectively). The revolutionary rise of Bayesian flexible age–depth modelling, which has helped to dramatically improve age frameworks for tephras and cryptotephras, was also reported (e.g. Blockley et al., 2007; Lowe et al., 2008b; Bronk Ramsey et al., 2015a; Blaauw et al., 2018).

An influential letter was written during the conference by the COT president and secretary on behalf of INTAV to the secretariat of the Japan Geopark Committee. Signed by more than 50 conference participants, the letter supported the application by Kirishima City for the Kirishima volcano system ("Kirishima Mountains") to become an accepted member of Geoparks Japan as Kirishima Geopark. The park was successfully certified as such later that year.

The meeting also featured 2 d in the field, during the first of which participants witnessed several small eruptions of Sakurajima just a few minutes after participants arrived at the stop (Fig. 8). Such impressive "organization" was greatly admired by all! Furthermore, numerous spectacular sections and excavations were viewed over the 2 d trip, including a gigantic outcrop featuring the voluminous Ito ignimbrite ($\sim$ 30 000 cal BP) (Fig. 8). This deposit is coeval with a widespread co-ignimbrite ash fall, first recognized in 1976, named Aira-Tanzawa ash (Aira-Tn) (Machida and Arai, 1976, 1983, 2003). A 3 d post-conference field trip across Kyushu also took place and included visits to Unzen volcano, Aso caldera, and Kuju and Yufu-Tsurumi volcanoes. Unusually, participants on the post-conference trip were given a small refund at the end, such was the efficiency and generosity of the leaders.

The conference proceedings, published in *Quaternary International* and comprising a record 31 scientific papers (Lowe et al., 2011b), were dedicated to the memory of Shinji Nagaoka (Moriwaki et al., 2011a). Editor-in-chief for *Quaternary International* at the time, Norm Catto, described this QI volume as "outstanding" and "one of the most commonly downloaded through the Elsevier website" (Norm Catto, personal communication, 2013). The volume paid specific tribute to the leading researcher of his generation in Japan, Hiroshi Machida; of him, Suzuki et al. (2011, p. 6) stated the following:

> Perhaps more than any other geoscientist from Japan, Hiroshi carried the insights and advances of tephra studies and their application in palaeoenvironmental and archaeological research, landscape processes, and volcanology and hazard analysis, to the outside world through a succession of papers and books written in English and through conference presentations.

Machida followed initially in the large footprints of Kunio Kobayashi, who, as well as founding COT, had a similarly compelling, outward-looking role in the 1960s and


**Figure 7.** (Top) Participants in the 2005 "Tephra Rush" meeting on 3 August 2005, in Dawson City, Yukon Territory, Canada (from Froese et al., 2008a, p. 2) (photo credit: Brent Alloway). The names of participants standing in an arc around the back are as follows (from left): Hiroshi Machida, Takaaki Fukuoka, David J. Lowe, Roland Gehrels, unknown, Stefan Wastegård, Warren Huff, Phil Shane, James Riehle, unknown, unknown, unknown, and John Westgate. The names of participants seated directly in front of the back row are as follows (from left): Hiroshi Moriwaki, unknown, unknown, Siwan Davies, Brad Pillans, unknown, and unknown. The names of participants seated in the second row from the front are as follows (from left): Shari Preece, Takehiko Suzuki, Paul Matheus, unknown, Nick Pearce, and Duane Froese; The names of participants seated in the front row are as follows (from left): Kaori Aoki, unknown, James Begét, Maria Gehrels, Brent Alloway, Caitlin Buck, Britta J. L. Jensen, and Grant Heiken. (Bottom) John Westgate (with megaphone) and Duane Froese on 1 August 2005, explaining the stratigraphy, chronology, composition, and distribution of the 833–850 CE White River Ash (eastern lobe) during the pre-conference trip from Whitehorse to Dawson (Froese et al., 2005) (photo credit: Brad Pillans).

early 1970s through his development of methods to characterize tephras both in the field and petrographically as well as by publishing papers in English to widen their impact (e.g. Kobayashi and Shimuzu, 1962; Momose et al., 1968; Kobayashi, 1969, 1972). Kobayashi also encouraged scientists from countries other than Japan to become involved in promoting tephra studies, including through appointment to COT's executive committee (John Westgate, personal communication, 2021).

### 3.10 Moieciu de Sus, Romania, 2018

There was an 8-year period before the next tephra meeting, the "Tephra Hunt in Transylvania" conference held (under the auspices of INTAV) in the Cheile Gradistei Fundata Re-

(a)


(b) (c) (d)

**Figure 8. (a)** Participants of the "Active Tephra" meeting held in Kirishima in May 2010, in the field on Kyushu, Japan. Sakurajima volcano (just visible in the background) erupted later that day during the trip (see below) (from Lowe et al., 2011a, p. 2) (photo credit: Koji Okumura). **(b)** Thick coastal exposure of the Aira tephra formation (erupted ~ 30 000 cal BP from Aira caldera), near Fumoto on the eastern coast of Kagoshima Bay, visited 13 May 2010. Initial deposits comprise plinian fall deposits (Osumi pumice) overlain by thin stratified (intra-plinian) pyroclastic flow deposits (Tarumizu ignimbrite) and then by thick, mainly non-welded ignimbrite, Ito ignimbrite (bulk volume > 450 $km^3$) (photo credit: David J. Lowe). **(c)** Small vulcanian eruption from the active Showa crater (Minamidake crater), Sakurajima volcano – one of two witnessed on 12 May (photo credit: David J. Lowe). **(d)** Participants examining Holocene tephras and humic buried soil horizons at the Tenjindan archaeological site of Jōmon era on the Osumi Peninsula near Kagoshima Bay, southern Kyushu, on the mid-conference field trip (13 May). The bright yellowish-orange tephra about 1.2 m below the land surface is Kikai-Akahoya tephra aged ~ 7300 cal BP. Artefact locations are marked with tags in the foreground (Moriwaki and Lowe, 2010) (photo credit: David J. Lowe). 

sort at Moieciu de Sus (near Braşov) set in the dramatic landscapes of the south Carpathian Mountains of Romania. Prior to this meeting, the INTAV committee members had been working on holding a meeting in Chile and Argentina for some years, but changes in circumstances for key personnel meant that it had to be shelved in 2016. The Transylvania meeting, with a theme of "Crossing new frontiers", is the largest tephra meeting that the commission has held thus far (Table 3): 92 participants from institutions in 21 countries attended, including 22 students (17 of whom were undertaking PhDs) (Lowe, 2018b). With nearly 100 attending, around double the number of countries normally represented, and the robust mix of senior, experienced, and emerging researchers, this meeting might be considered a "coming of age" for INTAV. Held from 24 June to 1 July, the meeting included 4 d in the field – a 1 d mid-conference trip that took in a memorable visit to Bran Castle and a 3 d post-conference trip with 32 participants that ended in Bucharest – as well as a public lecture where the complex geological setting of the region was introduced by Ioan Seghedi. A workshop for several dozen participants on Bayesian age modelling was led by Maarten Blaauw (Fig. 9). Such workshops (on various topics) have been a feature of a number of tephra meetings, in some cases being the main focus (e.g. Tokyo in 1993 and Portland in 2014 and 2017).


**Figure 9.** **(a)** Participants of the "Tephra Hunt in Transylvania" conference in the Perşani volcanic field on 26 June 2018, in the southern Carpathians, Romania, during the mid-conference field trip (from Abbott et al., 2020a, p. 2) (photo credit: Pierre Oesterle). **(b)** A distal occurrence of Y5 tephra, about 0.6 m thick, associated with the Campanian Ignimbrite eruption ca. 39 000–40 000 cal BP of the Campi Flegrei field (Italy), within loess on the Wallachian plains in southeast Romania near the Buzău River. Dan Veres is directly alongside the darker, slightly pinkish, fine-grained Y5 tephra deposit (photo credit: David J. Lowe). **(c)** Maarten Blaauw (far right) leading a Bayesian age modelling workshop during the conference on 27 June 2018 (photo credit: David J. Lowe).

Faithfully following the commission's enduring and important philosophy, only one session of oral papers was run during the Romanian conference (i.e. no parallel sessions were held) so that all participants could see all of the talks and thereby support ECRs as well as taking in keynote and other oral presentations.

In addition, the organizers placed equal value on poster papers, with all posters being displayed for the entirety of the conference, and they were featured in stand-alone poster presentation sessions. The special volume of ensuing papers, published as a double issue of the *Journal of Quaternary Science* (Abbott et al., 2020b), includes 27 scientific articles and is entitled "Crossing new frontiers: extending tephrochronology as a global geoscientific research tool". The volume was dedicated to the memory of Richard Payne (Abbott et al., 2020a; Bunting et al., 2020).

### 3.11 Other professional activities associated with COT

As well as the specialist tephra meetings described above, tephrochronologists of COT have been active since 1964 in convening and running tephra-focussed sessions or symposia, or leading field trips, in association with various commissions or full congresses of INQUA or IAVCEI (e.g. Smith, 1986; Eden and Furkert, 1988; Saito et al., 2016; Lane et al., 2017b; Hopkins et al., 2021a; Scott, 2021). Collaborative events have additionally been undertaken in conjunction with PAGES (e.g. Hall and Alloway, 2004) or other organizations such as the International Geological Congress (IGC); the US National Science Foundation (NSF); the Geological Society, London; and the UK Quaternary Research Association (QRA) (Appendix A).

COT members have also been heavily involved in a range of projects including the highly successful INTIMATE project (which was launched for the North Atlantic region at the 1995 Berlin INQUA Congress) in which tephrochronology has played a pivotal role (e.g. Davies et al., 2002, 2012;

Turney et al., 2004a, b; Alloway et al., 2007; Lowe et al., 2008b, J. J. Lowe et al., 2008c; Moriwaki et al., 2011b; Barrell et al., 2013; Blockley et al., 2014). In addition, studies on tephras or cryptotephras have featured at numerous national or regional meetings or specialist workshops (e.g. Smalley, 1980; Howorth et al., 1981; Suzuki and Nakamura, 2005; Dugmore et al., 2011; Benediktsson et al., 2012b; Austin et al., 2014a). Some of these meetings were built around multidisciplinary projects such as SMART (Synchronising Marine And ice-core Records using Tephrochronology), which was one of the first systematic projects investigating the cryptotephra record preserved within North Atlantic marine deposits (Austin et al., 2014b), and the RESET project (RESponse of humans to abrupt Environmental Transitions) (J. J. Lowe et al., 2015) (Appendix A).

## 4 Officers and membership, key events, and post-2007 funding

Here, we describe the leadership of the commission through its elected officers, as well as the commission's membership, through time. We cover the fortunes of the commission since the 1980s, including key events and protagonists (Sect. 4.3), before concluding with a discussion of funding and its expenditure when the commission operated as INTAV for 12 years from 2007.

### 4.1 Officers of COT and their roles

Until the Nagoya INQUA Congress in 2015, the commission committees (also called "executives"; see also Sect. 4.2) usually comprised three officers elected to serve the needs of COT: a president, vice president, and secretary (Table 4). A total of 29 people have filled the committee roles over the past 60 years, representing institutions in nine countries. The majority (22) of the officers has represented just four countries: UK (8 officers), New Zealand (5), USA (5), and Japan (4). Around half (14) of the officers have served 8 years or more, with the longest serving being Kunio Kobayashi (12 years), Takehiko Suzuki (12 years), and David J. Lowe (16 years, over two stints).

There has been ongoing support for COT through elected officers since the 1990s as new generations have emerged, including from the growing numbers of cryptotephra specialists. However, it must be said that to join the commission as an officer does entail dedication and, at times, intense bursts of work – such as developing, promoting, organizing, and running specialist field conferences or the tephra symposia at the INQUA congresses. Within IAVCEI, it is an expectation that a meeting is normally held by commissions within each inter-congress period, i.e. roughly every 4 years. As well as organizing these meetings, officers of the commissions have hosted business meetings for commission members, acquired funding (see below), developed and hosted websites, and, as editors, typically led the publication of articles following conferences in proceedings comprising collective issues of journals or books as negotiated with publishers.

In 2015, the INTAV committee was expanded to five officers: a president, an immediate past president, and three vice presidents (Table 4). This move was, in part, recognition that, in the age of the internet, a secretarial role had become less pivotal, but the main reasons were

- to enhance the general functioning capability of the committee to reflect a rapidly growing membership;
- to help spread the increasing load relating to the acquisition of funding and associated compliance;
- to develop extra capacity to cope with the workload in the busy 2015–2019 inter-congress period of simultaneously co-organizing the tephra meeting in Romania (2018) and the multiple tephra sessions planned for the Dublin INQUA Congress (2019);
- to provide editing support to the local organizing committee to publish the 2018 conference-related special issue (Abbott et al., 2020b);
- to widen the geographic representation and to include more cryptotephra specialists;
- to maintain experience while concomitantly encouraging ECR-members and improving gender balance.

### 4.2 Membership of COT

Until the early- to mid-2000s, membership of the commission under INQUA protocol was somewhat complex, comprising several categories, including officers, formal members, honorary members, and corresponding members, with the last representing by far the bulk of the membership. Formal members, usually respected specialists (or allied practitioners, such as palynologists or volcanologists, who applied tephrochronology closely to their research), were limited in number – for example, just six were listed for the 1965–1969 period (Neustadt, 1969, p. 90), nine were elected at the Christchurch INQUA Congress in 1973 (Kaizuka, 1974, p. 80), and 15 formal members (with voting rights) are recorded, along with ∼ 120 corresponding members, following the Berlin INQUA Congress in 1995 (Lowe, 1996a). (Honorary members are discussed below in Sect. 5.2.) Together, the formal members and officers comprised the equivalent of a committee, but because most or all of the commission's work was undertaken by the officers, the latter effectively became the "executive" or "executive committee".

From around 2002, membership was simplified and email lists of members were developed, amalgamating formal and corresponding members into a single email group (see also Sect. 5.3). The process began with the advent of the "TEPHRA" group of JISCMail (a national academic mailing list service in the UK) on 4 March 2002, which was set

**Table 4.** List of officers of the commission since 1961.

| Inter-congress period | Name of commission[a] | President | Vice president (VP) | VP | VP | Past president (PP) | VP (ECR rep) |
|---|---|---|---|---|---|---|---|
| 2019–present[b] | COT* (IAVCEI) | Britta J. L. Jensen (CA)[c] | Peter M. Abbott (CH) | Ian Matthews (UK) | Paul Albert (UK) | Takehiko Suzuki (JP) | Jenni Hopkins (NZ) |
| Inter-congress period | Name of commission[a] | President | VP | VP | VP | PP | |
| 2015–2019 | INTAV | Takehiko Suzuki (JP) | Britta J. L. Jensen (CA) | Peter M. Abbott (UK) | Victoria Smith (UK) and Siwan Davies (UK) | David J. Lowe[d] (NZ) | |
| Inter-congress period | Name of commission[a] | President | VP | Secretary | | | |
| 2011–2015 | INTAV | David J. Lowe (NZ) | Takehiko Suzuki (JP) | Victoria Smith (UK) | | | |
| 2007–2011 | INTAV | Siwan Davies (UK) | Phil Shane (NZ) | David J. Lowe (NZ) | | | |
| 2003–2007 | SCOTAV | Chris Turney (AU) | Siwan Davies (UK) | Brent Alloway (NZ) | | | |
| 1999–2003 | COTAV | Étienne Juvigné (BE) | Valerie Hall (UK) | Chris Turney (UK) | | | |
| 1995–1999 | COTAV/ COTS | James Begét (US) | Étienne Juvigné (BE) | Valerie Hall (UK) | | | |
| 1991–1995 | COT | Hiroshi Machida (JP) | James Begét (US) | David J. Lowe (NZ) | | | |
| 1987–1991 | ICCT | John Westgate (CA) | Hiroshi Machida (JP) | Paul van den Bogaard (DE) | | | |
| 1982–1987 | CEV (IAVCEI) | Bruce Houghton (NZ)[e] Colin Wilson (NZ) Grant Heiken (US) | | Wolf Elston (US) Stephen Self (US) | | | |
| 1977–1982 | COT | Stephen Sparks (UK)[e] | | Stephen Self (US) | | | |
| 1973–1977 | COT | Dragoslav Ninkovitch (US) | Yoshio Katsui (JP) | Colin Vucetich (NZ) | | | |
| 1969–1973 | COT | Kunio Kobayashi (JP) | Sohei Kaizuka (JP) | John Westgate (CA) | | | |
| 1965–1969 | COT | Kunio Kobayashi (JP)[f] | | | | | |
| 1961–1965 | COT | Kunio Kobayashi (JP)[f] | | | | | |

* For abbreviations, see Table 2. Gaps indicate non-appointment. [a] Affiliated with INQUA except where noted (with IAVCEI). [b] Interim committee to support the transition to IAVCEI. [c] The country abbreviations used are as follows: AU, Australia; CA, Canada; NZ, New Zealand; JP, Japan; CH, Switzerland; BE, Belgium; DE, Germany; UK, United Kingdom; US, United States of America. [d] David J. Lowe has effectively been an active "emeritus advisor" to the committee since 2019. [e] IAVCEI commissions at this time comprised two officers. Sigurdur Thórarinsson (Iceland) held an honorary president role in COT from 1977 to 1982 (Self and Sparks, 1981a; Elston and Heiken, 1984). Houghton and Wilson were joint leaders of CEV. Strictly, "COT" per se was defunct in this period (1982–1987), but many members participated as tephrochronologists in CEV-related activities (e.g. volcanological congress in New Zealand, 1986); thus, we include CEV for completeness. [f] Up until 1969, the COT executive evidently comprised only a president.

up by Chris Turney (based at Queen's University, Belfast, at the time). The purpose was to facilitate discussion around tephra issues as cryptotephra-based research began expanding in the UK and beyond. Membership was then widened by Siwan Davies on 11 November 2005, following a tephra workshop in Swansea in April 2005, to include SCOTAV members globally, with the aim being "to provide an important [international] forum for increased interaction and discussion amongst those involved with [all] tephra studies". Thus, JISCMail (TEPHRA) became the default membership list for SCOTAV and INTAV after 2007 (Lowe, 2008). When issues or queries required membership input or voting, members were notified via JISCMail. Today, under IAVCEI rules, members must formally sign up to COT within IAVCEI and pay a modest membership fee (which includes a reduced-fee option for ECRs).

### 4.3 Decline and rise of COT since the 1980s: key events and protagonists

#### 4.3.1 COT transforms to CEV

After the 1980 Iceland meeting, the need for COT was questioned. Some considered that COT "had reached its goals of communicating the utility of tephrochronology and tephra studies to the scientific community", chiefly with the publication of Westgate and Gold (1974) and Self and Sparks (1981c) (Elston and Heiken, 1984). Realization that research on explosive volcanism was rapidly expanding at this time led the secretary of COT to propose (in December 1982) that some members of the commission could serve as a nucleus for a proposed Working Group on Explosive Volcanism within IAVCEI. A proposal for such a group was submitted to the IAVCEI secretariat at the International Union of Geodesy and Geophysics (IUGG) meeting in Hamburg in August 1983. The IAVCEI executive committee officially approved adoption of the working group at the Hamburg meeting (Elston and Heiken, 1984; Schmincke, 1989, p. 234), and Grant Heiken was appointed president while Stephen Self was appointed secretary. Self was replaced in 1984 by Wolfgang ("Wolf") Elston. Sometime after, the working group was renamed the Commission on Explosive Volcanism (CEV). Bruce Houghton and Colin Wilson (co-leaders) led the CEV from 1986 following their preeminent roles in the highly successful IAVCEI International Volcanological Congress (centenary of 1886 Tarawera eruption) held in New Zealand in February 1986 (Schmincke, 1989). Retirements or the passing of some of the early protagonists of COT may have had an impact on this shift from INQUA to IAVCEI in the early 1980s. It also seems possible that the long hiatus since the first COT meeting in 1964 could have been another catalyst for change.

#### 4.3.2 Renaissance from 1987

In 1987, however, at the INQUA Congress in Ottawa, some people expressed the view that the needs of tephrochronologists were not being met under the CEV of IAVCEI. It was decided to make a request to the INQUA executive committee for the reinstatement of COT. John Westgate convened a meeting at the conclusion of the tephra symposium in Ottawa and then prepared a document justifying this aim. He presented it to the INQUA executive committee the next day. The executive decided to reinstate this group but under the title "Inter-Congress Committee on Tephrochronology" (ICCT). There would be a trial period of inter-congress length, and a decision to elevate to a full commission would be made at the next INQUA Congress. Looking back, it might seem that this "trial" was a bit harsh, but a more objective view is that the first quarter of a century of COT might be characterized as somewhat below par, with only two field meetings (1964, 1980), albeit tempered with the strong presence of COT at the INQUA Congress in Christchurch (1973) and the publication of both Westgate and Gold (1974) and Self and Sparks (1981c). In any event, the formation of ICCT in 1987 can be seen as a turning point for COT: the election of a full complement of officers in 1987 under Westgate's leadership, the successful tephra meeting in Mammoth in 1990, and the subsequent volume of ensuing papers (including the new tephra characterization protocols of Froggatt, 1992) edited by Westgate et al. (1992b) collectively demonstrated a renewed and strong commitment by ICCT and enabled COT to be restored as a formal commission of INQUA in Beijing in 1991 (Lowe, 1996a).

#### 4.3.3 Growth from the 1990s: emergence of modern cryptotephra studies and new techniques

The momentum was maintained with the PAGES-COT "Climatic impact of volcanism" meeting held in Japan in December 1993, the triple-discipline meeting held only a few months later in New Zealand in February 1994, and the meeting held in France in July–August, 1998 (Table 3). Membership by this time was strong, exceeding 100 (Lowe, 1996a). At the same time, cryptotephra studies of the modern era, as noted earlier, were advancing at pace (e.g. Pilcher and Hall, 1992, 1996; Merkt et al., 1993; van den Bogaard et al., 1994; Pilcher et al., 1995; Dugmore et al., 1996) and so a new cohort of graduate students, working on cryptotephras, was training in parallel with the more traditional graduates developing skills and expertise relating to visible tephras and associated proximal deposits in volcanically active countries (Froese et al., 2008a). It is also noteworthy that, following on from Froggatt's (1992) recommendations, John Hunt and Peter Hill undertook (in the 1990s) the first interlaboratory comparison exercise involving EPMA, targeting data quality, testing glass standards (including Lipari obsidian), and evaluating reproducibility (Hunt and Hill, 1993, 1996, 2001; Hunt et al., 1998).

The 2010 Active Tephra meeting in Kirishima, Japan, may be viewed as another turning point for COT, described as a "step-change" by Lowe et al. (2011a), because by then, or soon after, many cryptotephra specialists were graduating, some taking up research and/or lecturing positions, and therefore helping to develop new directions for research including studies in the marine environment and on ice cores. Thus, an increasingly global outlook for tephrochronology (sensu lato) began to accelerate from around that time (Riede and Thastrup, 2013; Smith et al., 2013; Davies et al., 2014; Davies, 2015; Ponomareva et al., 2015; Lane et al., 2017a).

We mentioned earlier that new dating techniques were reported at the 1990 Mammoth meeting, and Bayesian age modelling was also featured at the 2010 Kirishima meeting (built around ever-improving $^{14}$C-calibration curves and other age-related data, most recently including zircon double dating). These techniques, alongside improving and new analytical techniques for glass shards, especially involving EPMA and LA-ICP-MS that were developing through the 1990s and the 2000s, provided further drive to enable tephra and cryptotephra studies to flourish (e.g. Bitschene and Schmincke, 1990; Westgate et al., 1994; Hunt et al., 1998; Pearce et al., 1999, 2007, 2011, 2014; Platz et al., 2007; Kuehn et al., 2011; Hayward, 2012; Pearce, 2014; Tomlinson et al., 2015; Danišík et al., 2017, 2020). In particular, the need to date glass shards in distal or ultra-distal settings, where inappropriate or no mineral grains were present, helped lead to the development of the ITPFT method (Westgate, 1989). Moreover, the requirement to be able to analyse very small glass shards accurately (such as fine-grained glass in ultra-distal deposits in ice cores or in lacustrine or marine sediments) led to the development of improved probe and LA-ICP-MS methods in cryptotephra studies (Hayward, 2012; Alloway et al., 2013; Lowe et al., 2017a).

Thus, by the time the most recent commission-related meetings were held in 2015 (Nagoya, Japan), 2017 (Portland, USA), 2018 (Moieciu de Sus, Romania), and 2019 (Dublin, Ireland), the contributions of participants in the discipline were wide ranging and detailed i.e. the new research had both breadth and depth. An informal survey of commission members undertaken in 2017 (as part of an EXTRAS funding application to INQUA) showed that ECRs and PhD students made up a healthy 39 % of respondents, balanced by 53 % of established or senior scientists (along with 8 % of researchers associated with developing countries). Creditably, female tephrochronologists amounted to 39 % of respondents at that time (cf. male 61 %). We speculate that this gender imbalance may have tilted further towards an even more equitable status since the survey in 2017.

### 4.4 Funding acquired by INTAV since 2007 and its expenditure

The commission officers have always had to bid for funding, primarily from INQUA and also from PAGES. Funding and in-kind support have also been acquired from numerous geo-institutes, scientific societies, universities, city councils, and private companies relating to the hosting of events in various cities and countries. These funds have been used to support specialist meetings and/or for publishing special COT-endorsed volumes, such as Westgate and Gold (1974), or conference proceedings, such as Juvigné and Raynal (2001b). Since 2007 (earlier records of funding are not available), support from INQUA, especially through successive presidents of SACCOM until 2018, has been greatly appreciated. In particular, financial support, amounting to around EUR 35 000 in total from 2009 to 2018, mainly helped ECRs attend the following international field conferences and specialist (tephra skills) workshops:

- full tephra field meeting in Kirishima, Japan, in May 2010 (supported also by PAGES: Lowe, 2011b);
- Bayesian age modelling workshop in San Miguel de Allende, Mexico, led by Maarten Blaauw in August 2010 (supported also by PAGES: Blaauw et al., 2011);
- INTAV/TIQS Tephra in Quaternary Science workshop in Edinburgh, UK, on the Eyjafjallajökull eruption of Iceland, led by Andrew Dugmore in May 2011 (Dugmore et al., 2011);
- two respective tephra workshops in Portland, USA, in August 2014 and August 2017 (Kuehn et al., 2014; Bursik et al., 2017) (https://vhub.org/search/?terms=tephra+workshops, last access: 18 June 2022) (see Sect. 6.1 below);
- full tephra field meeting in Moieciu de Sus, Romania, in June–July 2018 (Karátson et al., 2018).

## 5 Aims of COT, life membership awards, and communication

In this section, we firstly outline and compare the aims of COT and how they have changed (or not) since the commission's founding. We then describe the circumstances around the development of the commission's honorary life membership awards. Finally, we outline how the commission has kept in touch with members.

### 5.1 Aims of COT, past and present

Prior to the 1961 Warsaw INQUA Congress, Kunio Kobayashi's pre-congress proposal for a COT included several broad aims, namely (1) to develop tephrochronology and apply it to Quaternary research and (2) to meet to report and discuss findings from different countries (as noted in Sect. 2.1). After the Warsaw conference, he expanded on these aims. Key aspects were to advance the principles of tephrochronology as well as methodology, to develop a global inventory (with regional maps) of the distribution of tephras including in ocean sediments, and to determine the numerical ages of tephras (Neustadt, 1969, p. 90). It is of interest that Kobayashi (1965, p. 786), after in-person discussions with Josef Frechen, a tephrochronologist in Germany, compiled a list with several more potential objectives, some prescient, including the following:

- study of widely distributed tephra deposits, such as thin ash layers in the Greenland ice sheet and in marine sediments, derived from very explosive, large-volume eruptions;
- development of microscopic methods to try to recognize the existence of tephra materials "even if they are in least [minimal or sparse] amounts";
- development of diagnostic petrographic and palaeomagnetic features on lavas to provide a basis for correlating related (co-magmatic) tephras;
- weathering studies on glass and associated clay minerals and, hence, the evaluation of potential environments during and since deposition;
- regular workshops/conferences to discuss ideas and compare and evaluate findings.

Although the aim of COT can now be expanded to include a reawakened focus on volcanic studies, the means to achieve this aim broadly remain the same. However, the application of tephrostratigraphy to inform volcanological studies, recently emphasized by Cashman and Rust (2020), has been maintained as an important focus in recently active volcanic countries such as New Zealand (e.g. Lowe, 1988; Newnham et al., 1999; Lowe et al., 2002; Smith et al., 2005; Hopkins et al., 2021a), Iceland (e.g. Thórarinsson, 1979; Pilcher et al., 1995; Thordarson and Höskuldsson, 2008; Óladóttir et al., 2012), Indonesia (Pearce et al., 2020), Chile (Romero et al., 2021), the USA (Crandell and Mullineaux, 1978; Heiken and Wohletz, 1987; Begét et al., 1994; Waitt and Begét, 2009; Cassidy et al., 2014), Japan (Machida, 1991, 1999, 2002; Tatsumi and Suzuki-Kamata, 2014; Schindlbeck et al., 2018), and Italy (e.g. Wulf et al., 2018; Leicher et al., 2021).

In general terms, the aim is to improve or develop new methods and protocols of tephrochronology (spanning field, analytical, geochronological, remote sensing, and digital/internet realms) to support and facilitate a broad variety of Quaternary research initiatives, ranging from palaeoenvironmental reconstruction to geomorphology, archaeology, and palaeoanthropology, as well as wide geochronological and volcanological applications. In addition, enhancing the global capability of tephrochronology for future research by training and mentoring emerging researchers remains paramount within the aims of the modern-day COT (Lowe et al., 2018). Centred around the concept of process–response systems, Paredes-Marino et al. (2022) provided a number of additional future challenges involving tephra studies, including the characterization of freshly fallen deposits to aid in the construction of enhanced ash-dispersion and ash-depositional models and, hence, to improve volcanic hazard analysis and its communication. Engagement with citizen scientists was also emphasized because it potentially helps build community understanding and resilience through education.

The seven objectives of the (completed) EXTRAS project provide a useful summary of the current major aims of COT in greater detail. We have expanded them to some extent as new ideas and research directions have arisen, and we have added a new objective – number 5 listed below – along with some relevant supporting references for it. The aims are to

1. evaluate and apply new and emerging technologies to identify and map proximal-to-distal (and ultra-distal) tephra and cryptotephra deposits and to establish their spatial and stratigraphic interrelationships in order to facilitate their use as chronostratigraphic units (including within loess, ice, speleothems, and other sedimentary deposits as well as in soils and paleosols) and as a basis for documenting and enhancing volcanic eruption histories (including through stratigraphic interfingering of tephra deposits from different volcanoes);
2. develop and evaluate new and emerging methods to mineralogically and geochemically (including isotopically) characterize tephra and cryptotephra constituents using formalized (and globally agreed upon) protocols that enhance data quality, quantity, and accessibility;
3. develop improved age models for tephra and cryptotephra deposits, including via Bayesian age modelling and wiggle-matching, thereby also improving existing age models for key volcanic, palaeoclimatic, archaeological, sedimentary, and other sequences using tephras and cryptotephras as appropriate;
4. evaluate and develop objective ways of correlating tephra and cryptotephra deposits from place to place, including using statistical techniques and numerical (i.e. quantitative) measures of probability of correlation or not;
5. recognize and map "transformed" tephra deposits (i.e. that have undergone morphological changes such as reworking, dislocation, or bioturbation) and, hence, evaluate new ways of reconstructing past environments using information provided by such transformations (e.g. Dugmore and Newton, 2012; Cutler et al., 2016, 2020;

**Table 5.** Honorary life members of the commission, their country of origin, and the year of award.

| | | |
|---|---|---|
| Siwan Davies | UK | 2019 |
| Guðrún Larsen | Iceland | 2018 |
| David J. Lowe | New Zealand | 2018 |
| James Begét | USA | 2015 |
| Hiroshi Moriwaki | Japan | 2015 |
| Andrew Dugmore | UK | 2014 |
| Vera Ponomareva | Russia | 2014 |
| Valerie Hall (1946–2016) | UK | 2011 |
| John Hunt | UK | 2011 |
| Étienne Juvigné | Belgium | 2007 |
| Hiroshi Machida | Japan | 2007 |
| Andrei Sarna-Wojcicki | USA | 2007 |
| John Westgate | Canada | 2007 |
| Colin Vucetich (1918–2007) | New Zealand | 1991 |
| Ray Wilcox (1912–2012) | USA | 1991 |

Blong et al., 2017; Dugmore et al., 2020; Thompson et al., 2021);

6. develop regional and ultimately global databases of high-quality mineral, geochemical, and other data (e.g. stratigraphic, chronologic, spatial, bibliometric) pertaining to tephra and cryptotephra deposits, and which are universally accessible (see Sect. 6.1 below);

7. maintain and enhance the global capability of tephrochronology for future research by supporting emerging researchers (ECRs) in the discipline through mentoring and training as well as in various other ways;

8. improve education to the wider community (outreach) about tephrochronology, its history, and its application and relevance to society, including through engagement with citizen scientists.

### 5.2 Life membership awards

During the ICCT period (1987–1991), one of the initiatives was to more clearly recognize those individuals who had made exceptional contributions to the discipline of tephrochronology. Ray Wilcox was the first member so elected at this time, along with Colin Vucetich soon after, with both being recorded as "honorary members" in 1991 (Lowe, 1996a). A simplification of membership categories in the early 2000s (Sect. 4.2) then led to the development of the "honorary life member" award (replacing honorary member). With Ray Wilcox and Colin Vucetich already acknowledged as (renamed) "honorary life members", another 13 recipients have been awarded life membership since 2007, all under INTAV (Table 5). The 15 honorary life members in total represent institutions in eight countries.

For the record, the life membership certificate (Fig. 10), designed by Betty-Ann Kamp, shows a schematic eruption plume representation based on the eruption of Mt Ruapehu stratovolcano (New Zealand) around 12:30 NZST (New Zealand Standard Time) on 18 June 1996 (photo in Lowe, 2011a, p. 108).

### 5.3 Communicating within COT and beyond

Communication amongst members was originally by irregular newsletter, with the most recent paper copies being those physically posted between 1991 and 1994 (Machida and Lowe, 1991; Lowe, 1992, 1994a). As described earlier in Sect. 4.2 on membership, the "TEPHRA" group of JISCMail (https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=TEPHRA, last access: 2 July 2022) was initiated ~ 20 years ago by Chris Turney in 2002 and then broadened to global coverage by Siwan Davies in 2005 "for increased interaction and discussion amongst those involved with tephra studies". That development, significantly, sparked a furious discussion about the term "microtephra" versus cryptotephra, kicked off by comments from John Lowe on 13 November 2005. This email system is still being used today by members of COT (e.g. for advertising PhD scholarships, forthcoming meetings or online workshops, among others). The archives have, in fact, been extraordinarily helpful in allowing us to provide some dates for events, names of people, etc., which would otherwise have almost certainly been lost forever.

JISCMail TEPHRA works alongside a Facebook page (https://www.facebook.com/IAVCEICOT/, last access: 18 June 2022) that was set up by Peter M. Abbott on 19 August 2015 (following discussion at the Nagoya INQUA Congress earlier that month) as well as a Twitter feed (https://twitter.com/IAVCEI_COT, last access: 18 June 2022). A tephrochronology website has been in place since about 2002 (under SCOTAV), which was originally established by Chris Turney (whilst at Queen's University, Belfast, UK) and then hosted by Brent Alloway (GNS Science, New Zealand). It was subsequently hosted by Phil Shane (University of Auckland) from September 2008 to November 2011 (under INTAV), by Victoria Smith (University of Oxford) until March 2017, and then by Takehiko Suzuki (Tokyo Metropolitan University) from March 2017 until 2021. A new COT website, to be hosted by IAVCEI (https://cot.iavceivolcano.org, last access: 18 June 2022), is being developed and is to be launched in the near future.

## 6 Legacies and future of COT

Key legacies from the pre-2019 commission that will be continued by the current COT include the organization of regular stand-alone international tephra conferences – approximately every 4 years – that combine conference and field elements, as well as workshops or online meetings or webinars

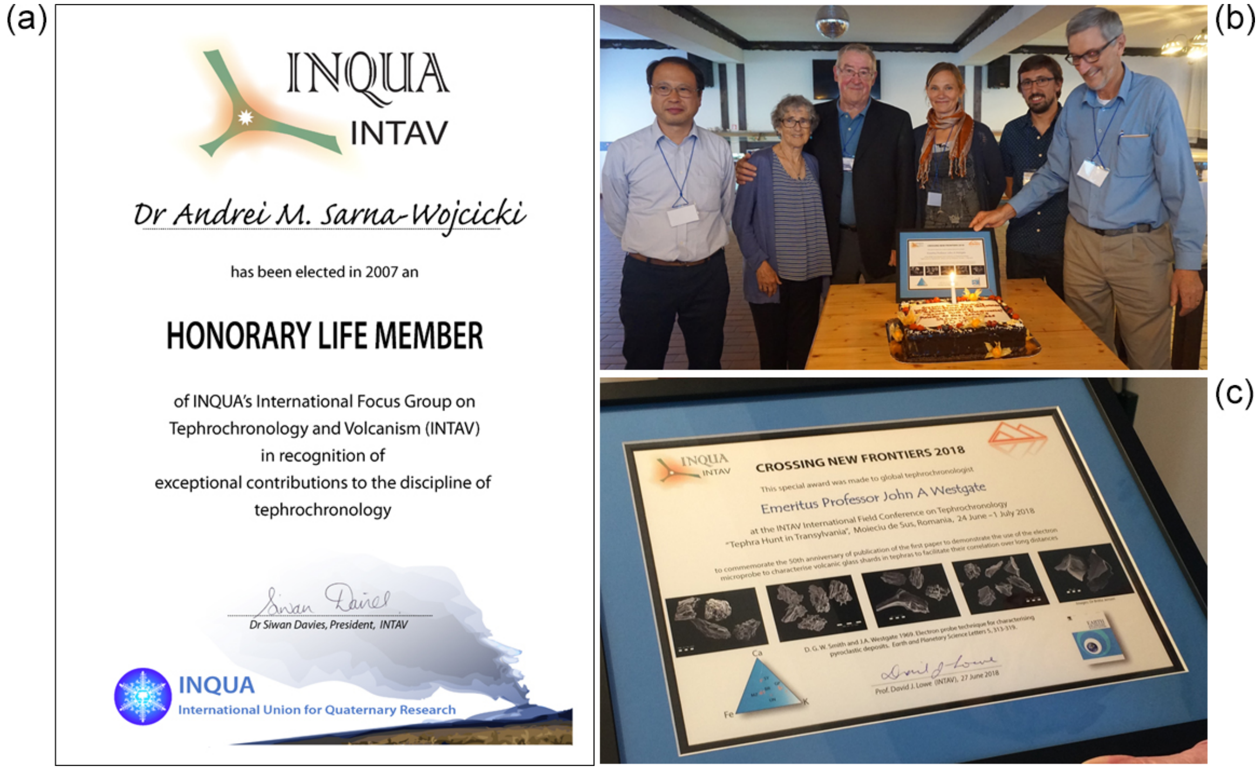


**Figure 10.** **(a)** Example of a life member certificate of INTAV. **(b)** Special cake and unique certificate prepared for the "Tephra Hunt" conference dinner (27 June 2018) to commemorate the 50th anniversary of the publication of John Westgate's pioneering paper on EPMA analysis of glass shards (Smith and Westgate, 1969). The photograph shows (from left) Takehiko Suzuki, Cora and John Westgate, Britta J. L. Jensen, Peter M. Abbott, and David J. Lowe (photo credit: anonymous). **(c)** Close-up view of the commemorative certificate presented to John Westgate. The scanning electron microscope images of glass shards (provided by Britta J. L. Jensen) represent the North American tephras that Westgate analysed in undertaking this seminal research (see Froese et al., 2008b) (photo credit: David J. Lowe).

on specific topics and/or the development of certain skills. In addition, COT will continue convening sessions/symposia at large-scale meetings, such as the IAVCEI scientific assemblies (e.g. tephra skills workshop held in Portland in 2017) and INQUA congresses (e.g. two sessions on tephra studies were held in Dublin in 2019, together generating the largest number of papers of any group at that congress: Fig. 11); supporting smaller (niche) meetings, workshops, and webinars; and reporting the results of tephrochronological studies in special issues of journals or books or specialist interactive websites. In total, two books and 10 tephra volumes, encompassing six different journals (footnote, Table 3), special workshop and other reports, abstract volumes, and field trip guidebooks (etc.), have been published by commission officers and others as a written legacy that has arisen mainly from international or national tephra conferences.

Commission-supported or endorsed methodological research projects, such as those conducted by Froggatt (1992), Hunt and Hill (1996), Suzuki (1996), Hunt et al. (1998), Turney et al. (2004b), Kuehn et al. (2011), Pearce et al. (2014), and Suzuki et al. (2014), remain a high priority, and COT will continue to provide support or endorsement for tephra-focussed projects that require input from the geoscience community. Three projects currently being undertaken with the endorsement of COT are described in the following sections.

### 6.1 Development of best practice protocols and databases

This project, examining all aspects of tephra studies, began in 2014 (Kuehn et al., 2014). Initially led by Steve Kuehn, Marcus Bursik, (the late) Solène Pouget, Kristi Wallace, and Andrei Kurbatov, many others have now been involved in the project as well. Best practice recommendation spreadsheets were updated in 2021 to version 3 (Abbott et al., 2021), and a manuscript which describes them has been accepted for publication (Wallace et al., 2022a). Since mid-2020, there is support for tephra in the StraboSpot field app (https://strabospot.org, last access: 18 June 2022) and a tephra-specific help file (https://strabospot.org/files/StraboSpotTephraHelp.pdf, last access: 18 June 2022). Staff of the US Geological Survey Alaska Volcano Observatory have used the protocols now for two field seasons. A new tephra community portal was developed in 2021 in collaboration with the EarthChem data repository (https:

**Figure 11. (a)** Large audiences, reflecting the new vibrancy of INTAV/COT as an important global discipline, were a feature of the two tephra sessions at the Dublin INQUA Congress in July 2019 (photo credit: David J. Lowe). **(b)** Takehiko Suzuki (INTAV president) presenting Siwan Davies with honorary life membership (photo credit: David J. Lowe). **(c)** INTAV's last executive committee (2015–2019), photographed on 30 July 2019, during the INTAV business meeting at the Dublin congress. The photograph shows (from left) Peter M. Abbott, Siwan Davies (seconded to committee in August 2017), Britta J. L. Jensen, Victoria Smith (who resigned in February 2017 after ~5 years of service), Takehiko Suzuki, and David J. Lowe (photo credit: anonymous). **(d)** Tephrochronologists and volcanologists enjoying the special tephra dinner in Dublin 2019 (photo credit: David J. Lowe).

//www.earthchem.org/communities/tephra/, last access: 19 June 2022), and this has templates for submitting information on samples, analytical method, and geochemical data. Recently updated examples of a "best practice dataset", based on (i) Summer Lake and (ii) June Lake tephras and their analyses, are available at Kuehn and Hostetler (2020) and Kuehn and Lyon (2020) respectively (see also Kuehn et al., 2021; Wallace et al., 2021). Steve Kuehn has 22 electron microprobe analysis method descriptors published with DOIs at EarthChem as the first of their kind using the new method-reporting format (Kuehn, 2021a, b).

Within the project, the further development of regional, thence global, databases is a priority because incomplete data are tending to limit correlation efficacy, especially as "exotic" cryptotephras are now being increasingly discovered many thousands of kilometres away from the source as ultra-distal deposits (e.g. Lane et al., 2017a; Lowe et al., 2017a; van der Bilt et al., 2017; Abbott et al., 2020a; Jensen et al., 2021; Krüger and van den Bogaard, 2021). The growing need to develop modern tephra databases was emphasized in discussions on JISCMail in 2006 that included contemporary comments from Chris Turney and Simon Blockley. However, it is notable that "Tephrabase", first provided in June, 1995, represents one of the earliest scientific databases to be made available on the internet (Newton et al., 1997, 2007) (see https://www.tephrabase.org/, last access: 18 June 2022). Some further examples of databases of various types include those of Machida and Okumura (1996), Larsen and Eiríksson (2008), Preece et al. (2011), Riede et al. (2011), Crosweller et al. (2012), Bronk Ramsey et al. (2015b), Gudmundsdóttir et al. (2016), Cameron et al. (2019), Meara et al. (2020), Nakanishi et al. (2020), Portnyagin et al. (2020), Hopkins et al. (2021b), Van Hazinga et al. (2021), Hopfenblatt et al. (2022), and DiMaggio et al. (2022). Progress in connecting such databases to larger, more comprehensive set-ups is exemplified in New Zealand by the availability of analytical and other data in Hopkins et al. (2021b): data are provided as Excel files in open-access supplementary materials in GNS Science's national database, Pet Lab (https://pet.gns.cri.nz, last access: 18 June 2022), and also as a file submission on EarthChem (Hopkins et al., 2020).

The best practices group has taken things even further towards a global or "next-generation" system using both SESAR (https://www.geosamples.org, last access: 19

June 2022) to generate unique, persistent global digital indices (IGSNs) for tephra samples, and EarthChem (https://www.earthchem.org/, last access: 19 June 2022) on the tephra portal (noted above). SESAR provides access to IGSNs for samples, specimens, and related sampling features from the natural environment (https://www.igsn.org/, last access: 18 June 2022). Registration with IGSN allows samples to be unambiguously cited and linked to data and publications as well as tracked through labs and repositories, making samples "findable, accessible, interoperable, and reusable" (FAIR). SESAR develops and operates digital tools and infrastructure for researchers, institutions, and sample facilities to store and openly share information about their samples. IGSNs can resister field sites and cores as well as samples. In the longer term, the vision is for everything to be connected. Hence, someone in the near future could undertake a geochemical search and, from there, find all related data and information from the labs for potentially correlative samples, all of the related publications, the researchers who did the work, and any other aspects including the original field sites (Steve Kuehn, personal communication, 2021). Most recently, a best practices "Tephra fusion webinar" was held over four sessions in February and March 2022 (https://tephrochronology.org/cot/Tephra2022/#, last access: 18 June 2022).

### 6.2 Microbeam trace-element characterization of new tephric glass reference material

Led by Nick Pearce, John Westgate, and Brent Alloway, this project builds on relatively recent progress in the development of analytical protocols for analysing tephra- or cryptotephra-derived glass shards (especially fine-grained shards), as undertaken (for example) by Morgan and London (2005), Kuehn and Froese (2010), Kuehn et al. (2011), Hayward (2012), Hall and Hayward (2014), Pearce et al. (2014), Iverson et al. (2017), and Lowe et al. (2017a). The project involves analysing trace elements and isotopes in glass shards from four carefully selected tephra-derived glass samples (A–D) using a range of analytical techniques, including LA-ICP-MS, ion probe, isotopic analyses, and minibulk methods. More than 30 analytical labs are involved in the project. Samples A, B, and D are rhyolitic, and sample C is phonolitic in composition. Pearce, Westgate, and Alloway checked the homogeneity of the trace-element compositions by LA-ICP-MS and ion probe analyses on multiple individual shards in each of the samples. They found that samples B, C, and D are homogeneous at the precision of the methods employed. However, sample A shows two populations (approximately two-thirds and one-third of the shards) based on trace-element analyses, with each population having a quite tight compositional range and being most easily separable by Ba content (Nick Pearce, personal communication, 2019, and via the project's "Second Circular"). Having the two compositional populations does not obviate its use as a reference glass; rather, it emphasizes the requirement to undertake analyses of a sufficient number of shards to accurately represent all of the different populations potentially in a glass-shard sample.

Splits of the precious glass separates A–D were dispatched to participating laboratories in December 2018, along with details about sample preparation and major element compositions. Templates for reporting analyses were provided in mid-April 2019. Further development of the project has been curtailed somewhat because of COVID-19, but we anticipate that a full analysis of the findings will be developed, together with recommended analytical protocols, and presented in due course (Nick Pearce, personal communication, 2019).

### 6.3 VOLCORE

Another recent development from the volcanological community is the comprehensive VOLCORE (Volcanic Core Records) database (Mahony et al., 2020). Although not strictly a COT initiative, it is nonetheless a very important advance for tephrochronologists and volcanologists alike; hence, we document it here. VOLCORE comprises a collection of 34 696 visible tephra (volcanic ash and lithological or grain size variations) occurrences reported in the initial reports volumes of all of the Deep Sea Drilling Project (DSDP; 1966–1983), the Ocean Drilling Program (ODP; 1983–2003), the Integrated Ocean Drilling Program (IODP; 2003–2013), and the International Ocean Discovery Program (IODP; 2013–present) up to and including IODP Expedition 381. Data include the depth below sea floor, tephra thickness, location, and any reported comments. The authors report that an approximate age was estimated for most (29 493) of the tephra layers using published age–depth models and that VOLCORE can be used as a starting point for studies of tephrochronology, volcanology, geochemistry, sediment transport, and palaeoclimatology (Mahony et al., 2020). No equivalent database is yet available for records of tephra (glass shards) and/or volcanic signals in ice cores.

## 7 Summary and conclusions

Although modern tephra studies effectively began globally in the 1920s, albeit in a limited way (Thórarinsson, 1981), and the terms tephra and tephrochronology were resurrected and coined respectively by Thórarinsson in 1944, the advent of an omnifarious group catering for tephrochronologists globally did not exist until 7 September 1961. On that day, the Commission on Tephrochronology was born within INQUA, thanks largely to the very substantial efforts of Kunio Kobayashi, along with those of Sohei Kaizuka and Masao Minato, backed by the National Committee of Quaternary Research of Japan, and various supporters including Thórarinsson and others. In this article, we have traced the development of COT, including both waxing and waning phases, and its zigzagging trajectory from one host organization (INQUA) to the other (IAVCEI), over the past 60 years. We have evaluated the commission's role in stimulating and supporting global tephra studies, with our main aim being to inspire new generations of tephrochronologists by preserving, documenting, and commenting on important historical events and leadership relating to the discipline. We additionally felt a substantial obligation to inform succeeding generations of COT's legacy because many of the commission members, especially ECRs, have shown a strong commitment to COT's continuation as a vigorous stand-alone international research group. Consequently, paraphrasing the concluding words of MacCracken and Volkert (2019, p. 135), we hope that our review has made a substantial contribution "to a common memory and tradition into the future about [the] personalities and groupings" that have responded scientifically to the numerous challenges involving tephrochronology and its application during the past 60 years (and earlier).

A critical turning point in COT's flagging fortunes is identified as taking place in 1987, after which the commission began to flourish, especially in the 1990s and thereafter. The "Active Tephra" meeting in southern Japan in 2010 was another key point in COT's development, as new dating methods and analytical techniques were being developed (or had been achieved) and many of the ECRs (including students) from around that time started to become – or had become – leaders in the discipline. Now, with strong numbers of members globally and expertise encompassing a much wider range of countries than previously, as well as a high proportion of ECRs working alongside a mix of experienced mid-career and senior practitioners, the commission might be seen as attaining close to its full potential as a global discipline in the past decade, which is most notably expressed in the three meetings held from 2017 to 2019. Good (2000, p. 260) defined "disciplines" philosophically as "ever-changing frameworks within which scientific activity is organised", with the "degree of consensus" with respect to conceptual, methodological, institutional, and social questions being the key to a discipline achieving "an identity". We would argue that such an identity has been attained for tephrochronology: support for tephrochronology and its application has never been stronger. For example, around 235 participants from 25 countries took part in the first workshop of the "Best practices: tephra fusion webinar" held on 10 February 2022 (Wallace et al., 2022b), and the COT Facebook site at the same time had recorded around 300 "likes". Renewed linkages with the volcanological community – unequivocal now that IAVCEI is the commission's sponsor – alongside the Quaternary palaeoenvironmental, archaeological, geochronological, and other communities, are also expanding.

We have documented and illustrated the nine inter-INQUA specialist tephra field meetings, each averaging nearly 60 participants, which have taken place in seven different countries, along with other activities, including the key involvement of tephrochronologists in international projects such as INTIMATE, RESET, or SMART; the organization of tephra sessions or symposia at full congresses of INQUA or in conjunction with its various commissions (e.g. loess, palaeoclimate, or palaeopedology commissions); and specialist workshops facilitated and/or run by COT in person or online. We have also explained some of the tephrochronological advances that occurred alongside or in conjunction with the development of COT, and we listed the commission's outputs of highly cited tephra-focussed journal volumes or books (12 in all) or specialist websites. The commission has been led by 29 officers in total, representing nine countries, and many have served 8 years or more on COT. A total of 15 recipients representing eight countries have been awarded honorary life membership of the commission.

It is somewhat ironical that the majority (or close to it) of participants at recent meetings has comprised those studying cryptotephras in countries without active or even recently active volcanism. Nevertheless, the continuing rise and impact of research by members of COT, both in volcanic and non-volcanic countries, including increasing proportions of ECRs and female tephrochronologists, ensure an exciting, enlightened, and, perhaps equally importantly, collegial and warm-hearted future for all tephrochronologists in continuing to advance the ever-changing frameworks forming the discipline.

## Appendix A

**Table A1.** Summary of some of the activities (including INQUA/IAVCEI sessions/symposia, regional workshops, etc.) associated with COT in addition to the nine specialist tephra conferences listed in Table 3.

| Activities from 1965 to 1999 | | Activities from 2000 to 2022 | |
|---|---|---|---|
| 1965 | INQUA Congress in Boulder (tephra session/s; field trips in the Pacific Northwest, central southern Alaska) (Neustadt, 1969) | 2000 | The fourth International INTIMATE Workshop, INQUA Palaeoclimate Commission and COTAV, Kangerlussuaq, Greenland (e.g. Turney et al., 2004b) |
| 1969 | INQUA Congress in Paris (tephra session/s; field trip in Massif Central) (Neustadt, 1969) | 2003 | INQUA Congress in Reno (tephra session/s; launch of Australasian INTIMATE project) (e.g. Shulmeister et al., 2006) |
| 1973 | INQUA Congress in Christchurch (tephra session/s; field trips in western North Island and central North Island) (Fairbridge, 1974) | 2005 | NSF Revealing Hominid Origins Initiative, International Tephra Working Group Workshop, Santa Fe, New Mexico (WoldeGabriel et al., 2005) |
| 1977 | INQUA Congress in Birmingham (tephra session/s) | 2007 | INQUA Congress in Cairns (tephra sessions; field trip on the Atherton Tablelands) |
| 1986 | IAVCEI International Volcanological Congress in Auckland–Hamilton–Rotorua (sessions on explosive volcanism, tephrochronology; field trips in North Island) (e.g. Houghton and Wilson, 1986) | 2011 | INQUA Congress in Bern (tephra sessions) |
| 1987 | New Zealand conference, Western Pacific Working Group of INQUA Loess Commission (field trip including North Island) (e.g. Smalley and O'Hara-Dhand, 2010) | 2012 | Tephra and Archaeology – Chronological, ecological and cultural dimensions symposium, Annual Meeting of European Association of Archaeologists, Helsinki |
| 1990, 1992, 1994 | Biennial UK Tephra Meetings in Edinburgh (1990), Belfast (1992), and Cheltenham (1994) (e.g. Hunt, 1999a) | 2014 | Tephra 2014 "Maximising the potential of tephra for multidisciplinary science", Portland, Oregon (https://www.tephrochronology.org/intav/Tephra2014/, last access: 18 June 2022) |
| 1991 | INQUA Congress in Beijing (tephra session/s) | 2015 | INQUA Congress in Nagoya (tephra sessions; numerous field trips involving tephras) |
| 1992 | IGC Tephra and volcanological meeting, Mt Tateyama, Japan | 2017 | Tephra 2017 "Best practices in tephra collection, analysis, and reporting: leading toward better tephra databases", IAVCEI Scientific Assembly in Portland, Oregon (https://www.tephrochronology.org/intav/Tephra2017/, last access: 18 June 2022) |
| 1995 | INQUA Congress in Berlin (tephra session/s; field trip in Eifel Volcanic Field) | 2019 | INQUA Congress in Dublin (tephra sessions) (see Sect. 6) and Tephra 2019 "Tephra standardization writing workshop" (https://www.tephrochronology.org/intav/Tephra2019/, last access: 18 June 2022) |
| 1995 | "Volcanoes in the Quaternary" meeting of the Volcanic Studies Group of the Geological Society and the QRA, London, UK (Firth, 1999; Firth and McGuire, 1999). | 2021 | American Geophysical Union AGU21 Fall Meeting (tephra and volcanic processes session) |
| 1999 | INQUA Congress in Durban (tephra session/s; formalizing link between S/COTAV and the INTIMATE project) (e.g. Turney et al., 2004a) | 2022 | "Best practices: tephra fusion webinars" (https://tephrochronology.org/cot/Tephra2022/#) (last access: 18 June 2022) |

**Code availability.** Any software codes mentioned are encapsulated within cited articles (or in associated supplementary material), are accessible via URLs cited in the text or references, or both.

**Data availability.** This article contains no datasets per se. All datasets referred to in the text are either provided in cited articles (including any supplementary material), or are accessible via URLs cited in the text and/or references.

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