Institution: University of Glasgow (UofG)		
Unit of Assessment: UoA7 (Earth Systems and Environmental Science)		
Title of case study: Radiocarbon dating reveals scale of counterfeiting of rare 19th- to mid-20th-century whiskies		
Period when the underpinning research was undertaken: 2013−present		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Prof. Gordon Cook	Professor	1978–present
Dr Elaine Dunbar	Laboratory Manager	2001–present
Period when the claimed impact occurred: 2017–present		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Sales of rare single-malt Scotch whiskies have risen ~600% over the past decade, with a current market estimated at GBP40 million annually in the UK alone. UofG research has made it possible to identify fraudulent products and, in many cases, to identify the distillation date to within 1–3 years, exposing the scale of counterfeiting of rare 19th- to mid-20th-century whiskies. Since 2017, UofG analyses of 106 samples for auction houses, whisky companies and individuals has established ~40% as counterfeit 'rare single malts' with a potential sales value of >GBP2 million. Distillation authentication enables the removal of counterfeit whisky from the secondary market. Concurrently, it has increased buyer confidence, ensured brand protection, and assisted criminal prosecutions to protect this valuable market.

2. Underpinning research

The UofG Radiocarbon Laboratory (the Laboratory) at the Scottish Universities Environmental Research Centre has developed the world's most extensive set of ^{14}C reference materials, including barley mash (draff) samples from the whisky-making process. Their research has focused on the refinement of natural reference materials which they supply to the global radiocarbon dating community through the third (TIRI) and fourth (VIRI) International Radiocarbon Inter-Comparison Studies [3.1–3.2]. These materials are used as standards across this community to underpin the age derivation of modern and ancient carbon-containing materials using accelerator mass spectrometry. The UofG laboratory uses these tools for the preeminent analytical accuracy, precision and speed in their dating of carbon-containing materials such as forensic samples (both human and animal) and biomass (and the added biomass to fossil fuels) through radiocarbon and stable carbon isotope measurements.

The laboratory recognised the importance of developing an independent calibration curve to extrapolate the $F^{14}C$ radiocarbon values beyond the published limit and well into the 21st century, for the dating of single malt Scotch whisky. $F^{14}C$ (fraction modern) values <1 indicate pre-nuclear origins and those >1 indicate the barley grew within the nuclear era. In 2011, the laboratory obtained samples of whiskies of varying known distillation years to understand how accurately ^{14}C could predict this. Work continued with the provision of NMS (New Make Spirit) and malt whiskies of known distillation year major international distilling companies (with Scotch premium brands at the core of their business), and Rare Whisky 101 who, together, have provided over 200 samples of known distillation year to develop the whisky-calibration curve.

In 2016, this new whisky-specific calibration curve was first used to analyse three malt whiskies supposedly originating from the late 19th century, including one bottle of single malt whisky purported to be from 1863. UofG analysis demonstrated that the bottle was actually distilled in 2005 and was counterfeit [3.3].

The Laboratory, led by Prof. Cook and Dr Dunbar, has received subsequent enquiries and liaised with contacts in the whisky industry, which revealed a demand in the market for product authentication using radiocarbon dating. Cook established valuable connections with Rare Whisky 101 (the only company to publish insight and intelligence to whisky collectors) as a means of establishing a route into the global market. Rare Whisky 101 also provided further known-age samples that enabled completion of a calibration curve encompassing the period from the mid-1950s to present. This has provided confidence to the whisky industry that the age data produced are accurate, as it removes any concern as to the relevance of the extant bomb calibration data derived from tree-ring measurements or concerns associated with "contamination" from another spirit of a different age, present in casks used for maturation. This curve has a 1-year offset from the extant bomb curve, consistent with an average 1-year delay between barley growth and distillation. In the absence of sufficient pre-1950 samples, the laboratory has used the extant tree ring data (1850–1955) with a 1-year offset to create a single-year whisky calibration curve from around 1850–present [3.4].

The research has been carried out by Dr Elaine Dunbar (Research Scientist) and Professor Gordon Cook, with technical help from Iain Murdoch. AMS radiocarbon measurements were carried out by Dr Derek Fabel, Dr Brian Tripney and Dr Sheng Xu.

3. References to the research

3.1 Radiocarbon, (2003) Volume 45, No 2. The Third Radiocarbon Intercomparison (TIRI) and The Fourth Radiocarbon Intercomparison (FIRI). 1990-2002 [available on request from HEI]

3.2 Scott, E.M., Naysmith, P. and Cook, G.T. (2018) Why do we need ^{14}C inter-comparisons? The Glasgow ^{14}C inter-comparison series, a reflection over 30 years. Quaternary Geochronology, 43, pp. 72-82. (doi:10.1016/j.quageo.2017.08.001)

3.3 Dunbar, E., Cook, G.T., Murdoch, I., Fabel, D. and Xu, S. (2017) Identification of fraudulent-age whiskies using accelerator mass spectrometry (AMS) radiocarbon (^{14}C) analyses. In: Proceedings of the 6th World Distilled Spirits Conference 2017. Chapter S7:1 1-5. ISBN 9781899043781. [available on request from HEI]

3.4 Cook, G.T, Dunbar, E, Tripney, B.G. and Fabel, D. (2020) Using carbon isotopes to fight the rise in fraudulent whisky. Radiocarbon, 62(1) 51–62. (doi: 10.1017/RDC.2019.153)

3.5 Repository of radiocarbon analysis reports by Cook, G., for individuals, whisky-related companies and auction houses are available on request.

4. Details of the impact

Whisky is a GBP4 billion export business for Scotland, with brand protection being hugely important for guaranteeing continuity of this trade [5.1]. Whiskies have risen to prominence in auctions and on the secondary market in recent years, with sales of rare single-malt Scotch whisky being recommended as an "asset class", rapidly rising in value [5.2]. Whisky was first added to the Luxury Investment Index published by the financial consulting firm of Knight Frank, who stated in their 2019 report that prices have risen over 35% in the past year, with UK auction totals of over GBP40 million — a rise of 600% over the past decade. With this rise in values have come heightened concerns regarding counterfeiting within the Scotch whisky industry and the general public. However, until recently there was no ability to confirm year of distillation in any authentication process, leaving industry reputations and buyers at risk from counterfeit goods.

Increased industry awareness of the problem of "fake whiskies"

Since 2016, the team have analysed 137 whisky samples of indeterminate age for whisky industry companies, private individuals and auction houses, and more than a third have been shown to be counterfeit. Dr Dunbar first raised the scale of this counterfeiting issue and its solution using

radiocarbon dating to the Worldwide Distilled Spirits Conference (2017) [3.3]. The work was published in the conference proceedings. Soon afterwards, the team was approached to write an article for the trade-oriented *Brewer and Distiller International Magazine*, bringing this issue to a wider audience. The issue was then brought to the attention of the drinks industry and the national and international public in December 2018 [5.3], when UofG radiocarbon dating revealed that of 55 bottles of Scotch whisky acquired from various sources through the secondary market, 21 were determined to be either outright fakes or not distilled in the year declared. All malt whisky samples purporting to be from around 1900 or earlier were found to be fake. This work was commissioned by Rare Whisky 101 [5.4] and has had a profound effect on the market [5.4-5.9], with results reported in both national and international mainstream and business news. Indeed, the Head of Whisky for Bonhams noted that "***after a number of pieces exposing the prevalence of 'fakes' were published in December 2018, there has been an increased public awareness of the problem and its possible solution through radiocarbon dating. It was at this time that I became aware of SUERC as leaders in this field***" [5.5]. The infiltration of 'fake whiskies' into all routes to market demonstrates that this problem involving high-value spirits is much more prevalent than originally thought, with an estimated GBP41 million worth of fake spirits currently circulating in the secondary market. "***Radiocarbon dating can be of the greatest importance in highlighting the worst and most valuable examples when fraudulent whisky comes onto the market***" [5.5].

[**Text redacted**].

Cook and Dunbar have worked more recently with brand owners looking to authenticate high-value casks, where age is critical to value. They recently analysed a cask of 1970's whisky to be purchased for GBP2.8 million. Confirmation of age authenticity gave the buyer confidence and ensured that the real value of the product was realised upon sale [5.4]. Analyses have been undertaken on behalf of the Metropolitan Police Force [5.9] in pursuit of a criminal case involving the sale of high-cost single malt whiskies.

The Laboratory's research has thus provided assurance to:

I. Retailers and auction houses, with a recommendation that "old, rare, valuable" bottles of malt whisky and other spirits must be sold with an accompanying certificate to prove age.
II. Brand Owners looking to authenticate "archive" bottles
III. Brand Owners looking to authenticate casks of rare whisky.

Change in professional practice in auction houses

A survey of 23 specialist whisky auction houses in the UK and internationally indicated that perceived difficulties in the resealing of bottles of rare whisky following radiocarbon date certification was a significant barrier to their uptake of this technique. In response to these concerns, the UofG is working with technology company Everledger to provide tamper-proof seals to accompany the radiocarbon dating analysis. The tamper-proof seal is applied to each bottle post-analysis, with Blockchain and near-field communication (NFC) technologies allowing a unique digital identity to be created. These will allow full and secure provenance tracking for each radiocarbon dated bottle, in perpetuity. ***"Whether it's fine whiskies or precious gemstones, the authenticity and backstory can be equally as important as the item itself. Organisations like SUERC lead the way when it comes to protecting, and increasing, the value of these prized assets, while defending the industry from fraudsters. By offering a complete solution including the intelligent bottle closures and the Everledger Platform, we're helping the likes of SUERC to further enhance the vital work that they do"*** [5.10].

5. Sources to corroborate the impact

5.1 https://www.thedrinksbusiness.com/2018/06/the-uk-loses-218-million-every-year-from-counterfeit-wine-and-spirits/ [also available as PDF]
5.2 A database of confidential reports to auction houses, distillers and owners is available to assessors upon request, given the sensitive nature of the contents of these statements, indicating potentially identifiable crime reports.
5.3 Database of media reports highlighting the role of radiocarbon dating in the identification of counterfeit whisky.
5.4 Testimonial: Rare Whisky 101
5.5 Testimonial: Head of Whisky, Bonhams.
5.6 Letters of support from distillers
5.7 Testimonial: Founding Member, Los Angeles Whisky Society
5.8 Testimonial: Whisky Auctioneer
5.9 Testimonial: Metropolitan Police Force
5.10 Memorandum of Understanding: Everledger and University of Glasgow