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EXPERT AGE DETERMINATION OF 4VW AND 4X HADDOCK OTOLITHS BY NATIONAL AND INTERNATIONAL LABORATORIES

by

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Abstract

Reference collections of sectioned otoliths from the 4VW and 4X haddock stocks were circulated to 5 national or international laboratories experienced in ageing haddock or related species. All of the laboratories (Pacific Biological Station, Woods Hole, Lowestoft, Norway, Aberdeen) were reasonably consistent in their interpretation of the otoliths, particularly those of 4X haddock. Graphical and statistical comparison of the data demonstrated that all used virtually identical criteria for interpreting annuli: differences were generally associated with the presence/absence of a single annulus in young haddock. By contrast, there were large differences between the consensus age interpretation and that of the previous St. Andrews ager of 4VWX haddock: 4VW fish with a consensus age of more than 3, and 4X fish with a consensus age of more than 4, were aged significantly and substantially lower by the St. Andrews ager, with the divergence increasing with age. Ages by the previous ager were often 50% or less than that of the consensus age for 4VW haddock. Growth curves based on the consensus age confirm previous suspicions of slower growth in 4VW haddock relative to 4X, with longevities of at least 15 years in each. While consensus does not necessarily imply accuracy, the consistency of so many experienced and independent ageing laboratories strongly suggests that age-based 4VW and 4X haddock stock assessments carried out since 1985 were in serious error. A radiochemical validation study to assess the accuracy of the consensus ages is now in progress.

Résumé

Les collections de référence d'otolithes sectionnées provenant des stocks d'aiglefin de 4VW et de 4X ont été confiées à cinq laboratoires nationaux ou internationaux ayant de l'expérience dans la détermination de l'âge de l'aiglefin ou d'espèces connexes. Tous ces laboratoires (Station de biologie du Pacifique, Woods Hole, Lowestoft, Norvège, Aberdeen) ont été raisonnablement uniformes dans leur interprétation des otolithes, en particulier de celles de l'aiglefin de 4X. Les comparaisons graphiques et statistiques des données démontrent qu'ils ont utilisé des critères virtuellement identiques pour l'interprétation des anneaux; les différences constatées étaient généralement liées à la présence ou à l'absence d'un anneau unique chez les jeunes aiglefins. En revanche, les écarts se sont avérés importants entre leur interprétation consensuelle des âges de l'aiglefin de 4VWX et celle qui avait été réalisée auparavant par le spécialiste de la détermination de l'âge de St. Andrews. Ainsi, les âges consensuels établis respectivement à plus de 3 pour l'aiglefin de 4VW et à plus de 4 pour l'aiglefin de 4X étaient bien supérieurs aux âges déterminés par le spécialiste de St. Andrews, l'écart augmentant avec l'âge. Les âges établis par ce dernier étaient souvent inférieurs à l'âge consensuel pour l'aiglefin de 4VW, dans une proportion allant jusqu'à 50 %. Les courbes de croissance fondées sur l'âge consensuel confirment les soupçons antérieurs de croissance plus lente de l'aiglefin de 4VW par rapport à celui de 4X, la longévité étant d'au moins 15 ans dans chacun de ces stocks. Quoique consensus ne soit pas nécessairement synonyme d'exactitude, la constance des résultats d'un tel nombre de laboratoires de détermination de l'âge expérimentés et indépendants porte nettement à croire que les évaluations d'âge des stocks d'aiglefin de 4VW et 4X réalisées depuis 1985 étaient gravement erronées. On effectue actuellement une étude de validation radiochimique pour déterminer l'exactitude des âges consensuels.

Introduction

Responsibility for the age determinations of the 4VW and 4X haddock stocks was transferred from the St. Andrews Biological Station to the Bedford Institute of Oceanography in 1993. In the process of training new haddock age readers at BIO, serious inconsistencies between the age interpretations of the primary St. Andrews age reader and those of other experienced age readers from BIO and the NMFS laboratory in Woods Hole, suggested that the post-1984 St. Andrews age interpretations for those stocks might be in error. More specifically, the St. Andrews ages were skewed towards much younger ages, resulting in a longevity on the order of 7 years, rather than the 15 years observed by others. As a result of those suspicions and in light of the absence of secondary agers, all ageing of the two haddock stocks was suspended, and the accuracy of post-1985 age-based stock assessments (using the the ages of the primary St. Andrews ager) cast into doubt. However, in the absence of comparative age determinations using otoliths of known age, the accuracy of the St. Andrews haddock ages could be neither confirmed nor denied. The accuracy of age interpretations of other species and stocks by the remaining St. Andrews age readers was not called into doubt as part of this exercise.

In 1994, a two-pronged solution to the haddock ageing problem was implemented. The first component involved the initiation of a radiochemical age validation study (eg- Campana et al. 1990) to determine the accuracy of ageing guidelines developed at a 1993 4X Haddock Ageing Workshop. This study is now underway, and will allow us to assess the accuracy of our age determinations, at least on average. However, since the radiochemical assays rely on pooled otolith samples, the results cannot be used to assess the accuracy or precision of individual age interpretations, either within or among age readers. Thus a second component to the study was implemented, involving the circulation of reference collections of sectioned haddock otoliths to five expert ageing laboratories around the world. The consensus age interpretations which resulted will soon be used to test new age readers and monitor ongoing ageing precision. Of more immediate importance, and the subject of this report, is the use of these consensus ages to determine the relative ease of ageing the 4VW and 4X haddock stocks and to infer the magnitude of the ageing error in post-1984 haddock ages.

Materials and Methods

Haddock otolith reference collections for both the 4VW and 4X stocks were assembled from existing and newly-sectioned plates. Each collection consisted of around 200 transverse sections of pairs of sagittal otoliths from the commercial fishery, collected at various times of the year from throughout the stock area. The 4X collection was based on 1991 samples, while that for 4VW was based on 1989 and 1991 samples. Each otolith pair was numbered for cross reference with an accompanying data recording sheet, on which was also marked the date of collection. Fish lengths were not available to the age readers.

Each reference collection was circulated to 5 national and international laboratories experienced in ageing haddock or related species. These laboratories included those at Nanaimo (Pacific Biological Station), Woods Hole (Northeast Fisheries Center), Lowestoft (Fisheries Laboratory), Aberdeen

(Marine Laboratory) and Norway (Institute of Marine Research). Most of the same otoliths had been interpreted previously by a single age reader at the St. Andrews Biological Station. The data which were returned by each laboratory were in terms of age (rather than annulus count), adjusted for a 1 January birthdate. Since many laboratories returned age interpretations by more than one age reader, only a single interpretation was used in the analysis which follows (or the consensus, if provided).

To provide each laboratory with a reference point for the position of the first annulus (which is stock-specific), otolith dimensions from haddock completing their first year of life (in the spring) were obtained from several sources. Length frequency plots from spring RV surveys of 4X (1979-83) and 4VW (1989 and 1994) consistently showed obvious modes at 14-18 cm which could only be attributed to age 1 fish. A similar mode (13-14 cm) was observed in a 29 November 1994 collection on Emerald Bank, near the end of the growing season. Using the relationship between otolith length/width/thickness and fish length (Campana unpublished; Hunt 1992), haddock which had just completed their first year of life and which should have been producing their first annulus (translucent zone) would be expected to have a first annulus of 3.0 mm width and 1.4 mm thickness. These expected dimensions compared favourably with measurements of presumed first annuli (2.9 and 1.2 mm, respectively) in a random sample (n=12) of sectioned 4X haddock otoliths. Therefore, all laboratories were notified *a priori* of the expected dimensions of the first annulus (3.0 mm width; 1.4 mm thickness).

The consistency of the paired age comparisons was assessed with age bias plots (Campana et al. 1995), while the coefficient of variation (CV) was used as a measure of precision (Chang et al. 1982). Percent agreement is a poor measure of precision (Chang et al. 1982; Campana et al. 1995) and was not used.

Results and Discussion

All five of the laboratories (Nanaimo, Woods Hole, Lowestoft, Norway, Aberdeen) were surprisingly consistent in their interpretation of the reference otoliths, particularly those of 4X haddock. Mean differences seldom exceeded one year for any given age category. Given that only one of the laboratories (Woods Hole) had ever seen otoliths from 4VW or 4X haddock in the past, the level of agreement was excellent, and suggested that there were no strong reasons why Scotian Shelf haddock could not be aged with good precision in the future. Ageing precision was somewhat less for the 4VW otoliths than for the 4X otoliths, confirming our suspicion that 4VW haddock are intrinsically more difficult to age.

Pairwise comparisons among the results of the five laboratories showed two predominant patterns: absolute consistency and a consistent 1-yr offset (Fig. 1). The Lowestoft, Woods Hole and Aberdeen labs showed absolute consistency, which is indicative of zero bias and the use of identical criteria for interpreting annuli (Fig. 2). Comparisons of the Nanaimo ages (and to a lesser extent Norway) with those of the other labs showed strong consistency, but with a consistent 1-yr offset (Figs. 1, 2). In other words, all of the labs used the same criteria for interpreting the annuli, but the Nanaimo age reader saw one additional annulus near the core of each otolith. The criteria used by the Norwegian age reader appeared to differ slightly from those of the others, at least in the case of the 4VW otoliths. Unfortunately, there were too few otoliths of 1 and 2-yr old fish to determine whether the Nanaimo or the Lowestoft interpretation pattern best represented the actual pattern. On the basis of length frequency modes in RV survey data, it would appear unlikely that age 1 and 2 haddock could be as large as indicated by the Lowestoft-Aberdeen-Woods Hole data. On the other hand, the reference otoliths came from commercial samples, which would have selected for fast-growing young fish. Therefore with the existing data, it is not possible to determine which pattern, if either, is correct.

There were large differences between the age interpretations of every laboratory and that of the previous St. Andrews ager (Fig. 2). Otoliths with a consensus age of more than 3 (more than 4 in the case of 4X), were aged significantly and substantially lower by the previous St. Andrews ager, with the divergence increasing with age (Fig. 3). Ages by the previous ager were often 50% or less than that of the consensus age for 4VW haddock. While consensus does not necessarily imply accuracy, the consistency of so many experienced and independent ageing laboratories strongly suggests that age-based 4VW and 4X haddock stock assessments carried out since 1985 were in serious error. While the apparent error was most acute for older fish, it would be expected to affect the age assignment of more than one half of the catch in recent assessments of 4X haddock (Hurley et al. 1994). The apparent underageing would result in an artificially rapid decline in the apparent abundance of the older fish, leading to artificially high fishing mortalities for those age groups.

Growth curves based on the consensus age confirm previous suspicions of slower growth in 4VW haddock relative to 4X, with longevities of at least 15 years in each (Fig. 4). While few otoliths from young fish were present in the reference collections, analysis of RV length frequencies suggest that the stock divergence in size at age is minimal at ages 0 and 1.

Several measures have been taken to address the haddock ageing problem and to minimize the likelihood of its repetition. Given that the responsibility for ageing 4VW and 4X haddock now lies at BIO, the previous haddock ager at St. Andrews has been assigned other duties. The remaining haddock agers in St. Andrews were not associated with the problem described here, and in any event, are now monitored through periodic secondary ageing and other quality control measures (E. Trippel, pers. comm.). Routine ageing of 4VW and 4X haddock otoliths will be restarted at BIO only after the consistency of BIO age readers is checked against the internationally accepted standards provided by the reference collections. Subsequently, all stocks and samples aged at BIO will be monitored for both bias and precision by continuous secondary ageing, with periodic checks against the reference collections. Finally, a radiochemical validation study to assess the accuracy of the consensus haddock ages is now in progress.

Acknowledgements

I sincerely thank my national and international colleagues for making possible the age comparisons of the reference otolith collections: Shayne MacLellan and Laura Richards at the Pacific Biological Station in Nanaimo; Mike Easey at the Fisheries Laboratory in Lowestoft; Andrew Newton and the age readers at the Marine Laboratory in Aberdeen; Lars Kalvenes and Kjell Nedreeas at the Institute of Marine Research in Norway; Nancy Munroe, Jay Burnett and Frank Almeida at the Northeast Fisheries Center in Woods Hole. Keith Brander (Lowestoft) and Mike Heath (Aberdeen) made valuable suggestions for contact names. I also thank Chris Annand, Diane Beanlands, Peter Comeau, Al MacDonald, Jim Simon and Gerry Young for preparing the reference collections and extracting the RV data. Gary Melvin kindly collected samples of young haddock as part of his RV survey. Chris Annand and John Neilson provided helpful comments on the manuscript.

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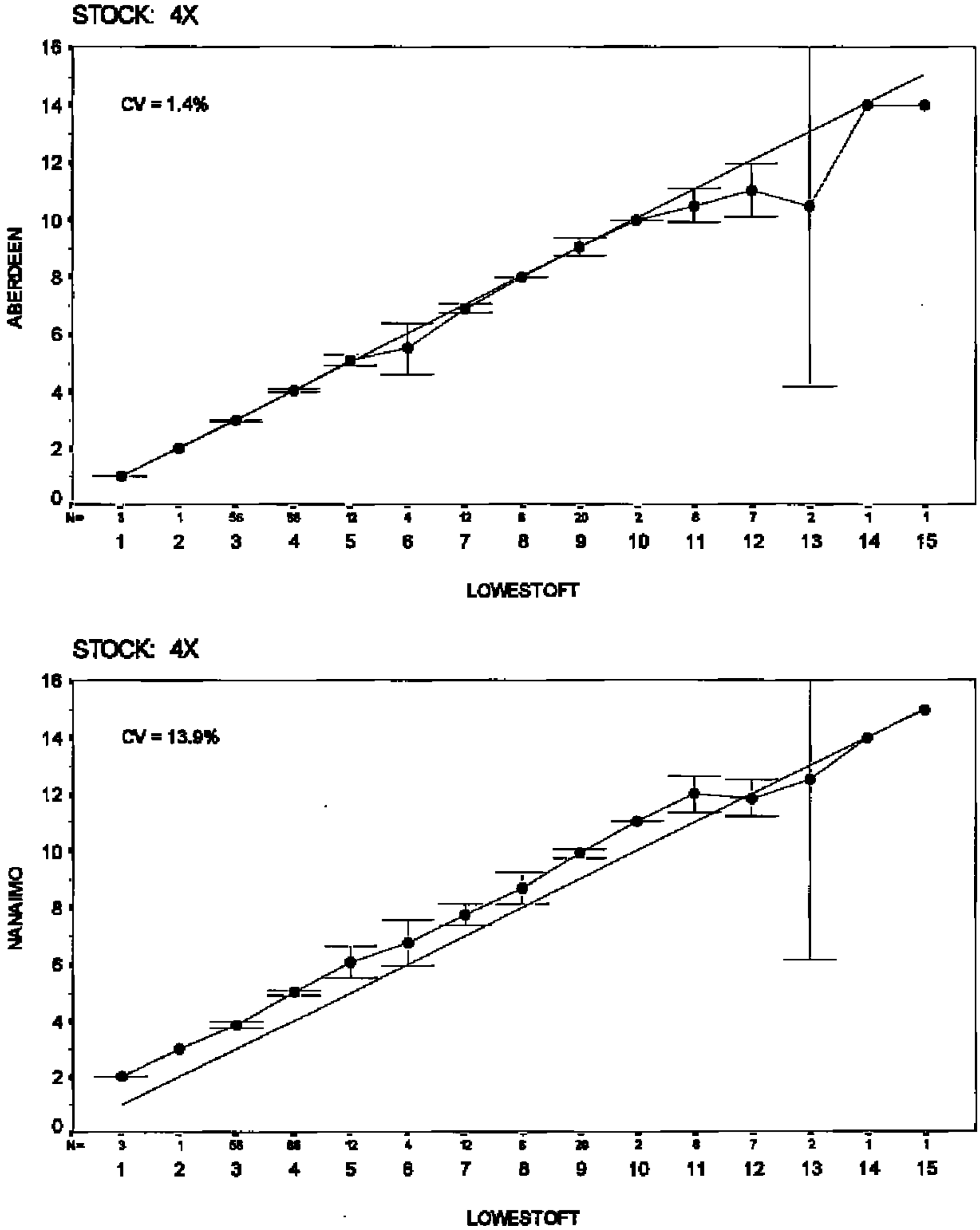

Fig. 1. Examples of pairwise age comparisons between two of five international ageing laboratories who examined the MFD haddock otolith reference collection. The age bias plots show the 95% confidence interval around each age category for one laboratory in relation to that of the other laboratory. The 1:1 line shows the relationship expected of zero ageing bias. (Top panel) Example of excellent consistency between two sets of age determinations. On average, both laboratories counted the same number of annuli with a low CV. (Bottom panel) Example of excellent consistency between two laboratories, but with a one year offset eg- Nanaimo counted one more annulus in each otolith than did Lowestoft, but did so consistently.

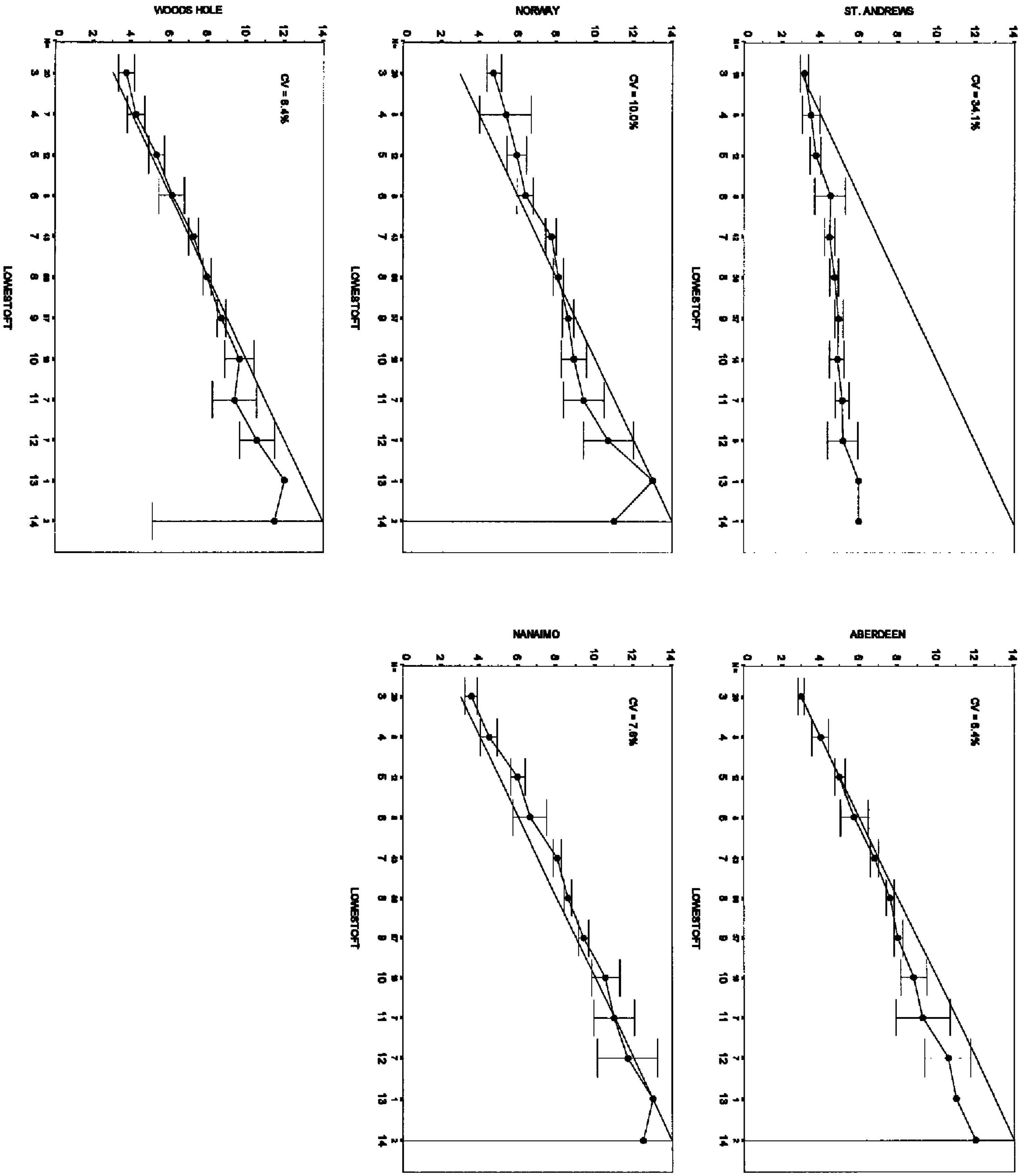

Fig. 2. Age bias plot for each pairwise age comparison among the 5 laboratory sites and St. Andrews. 4X + 4VW haddock comparisons are presented on alternate pages.

2a. 4VW ages in comparison with those of Lowestoft.

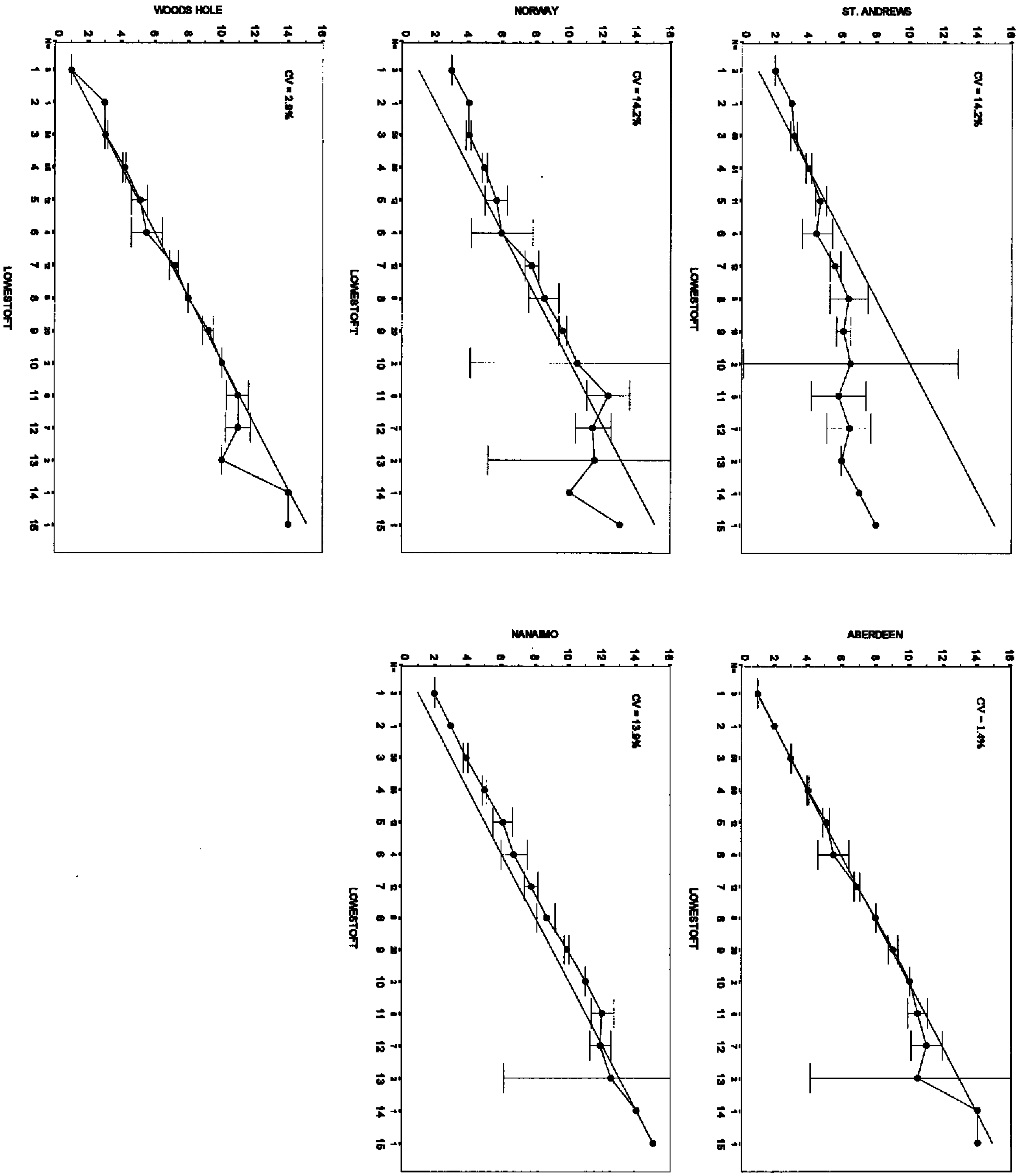

Fig. 2b. 4X ages in comparison with those of Lowestoft.

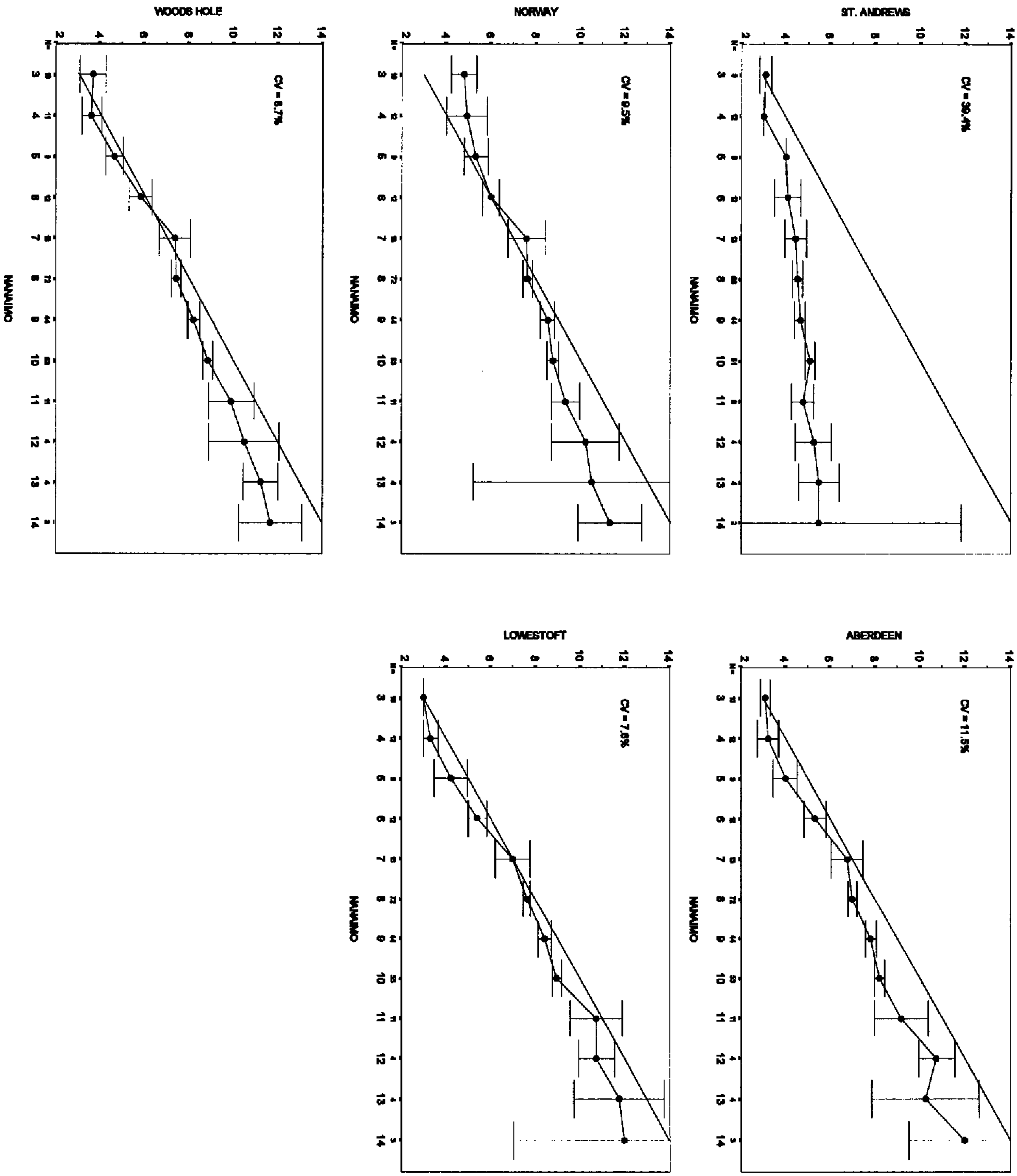

Fig. 2c. 4VW ages in comparison with those of Nanaimo.

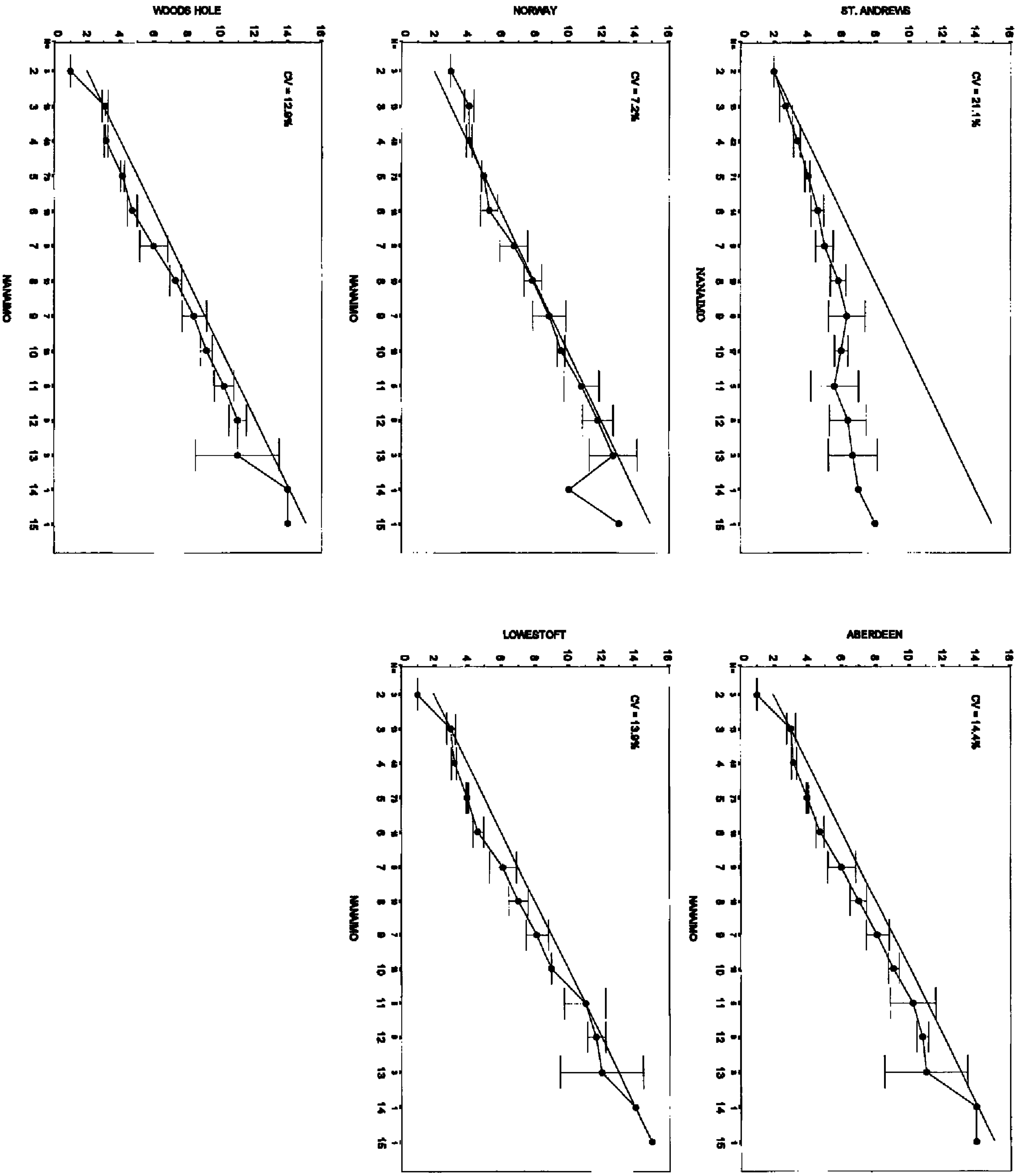

Fig. 2d. 4X ages in comparison with those of Nanaimo.

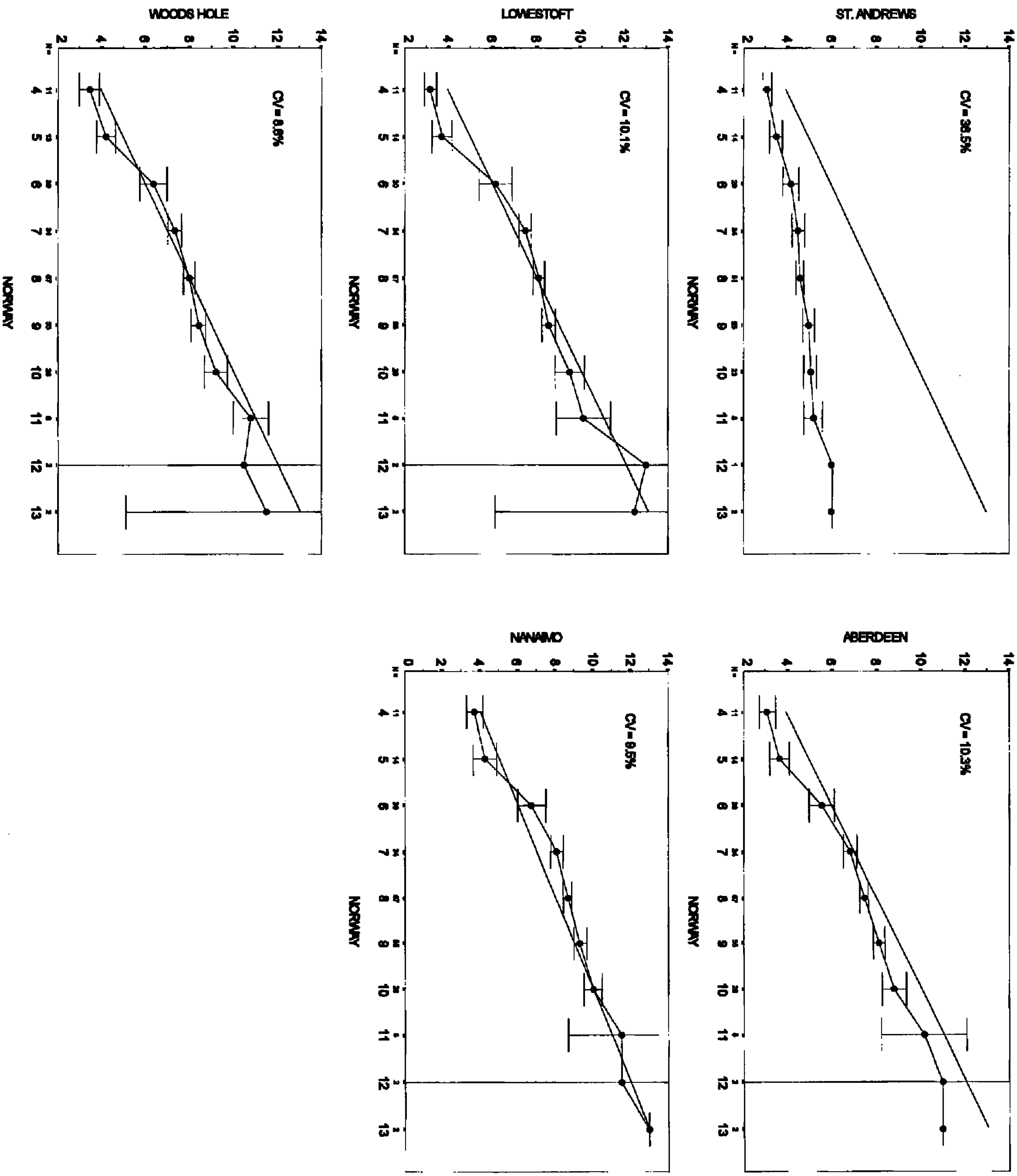

Fig. 2e. 4VW ages in comparison with those of Norway.

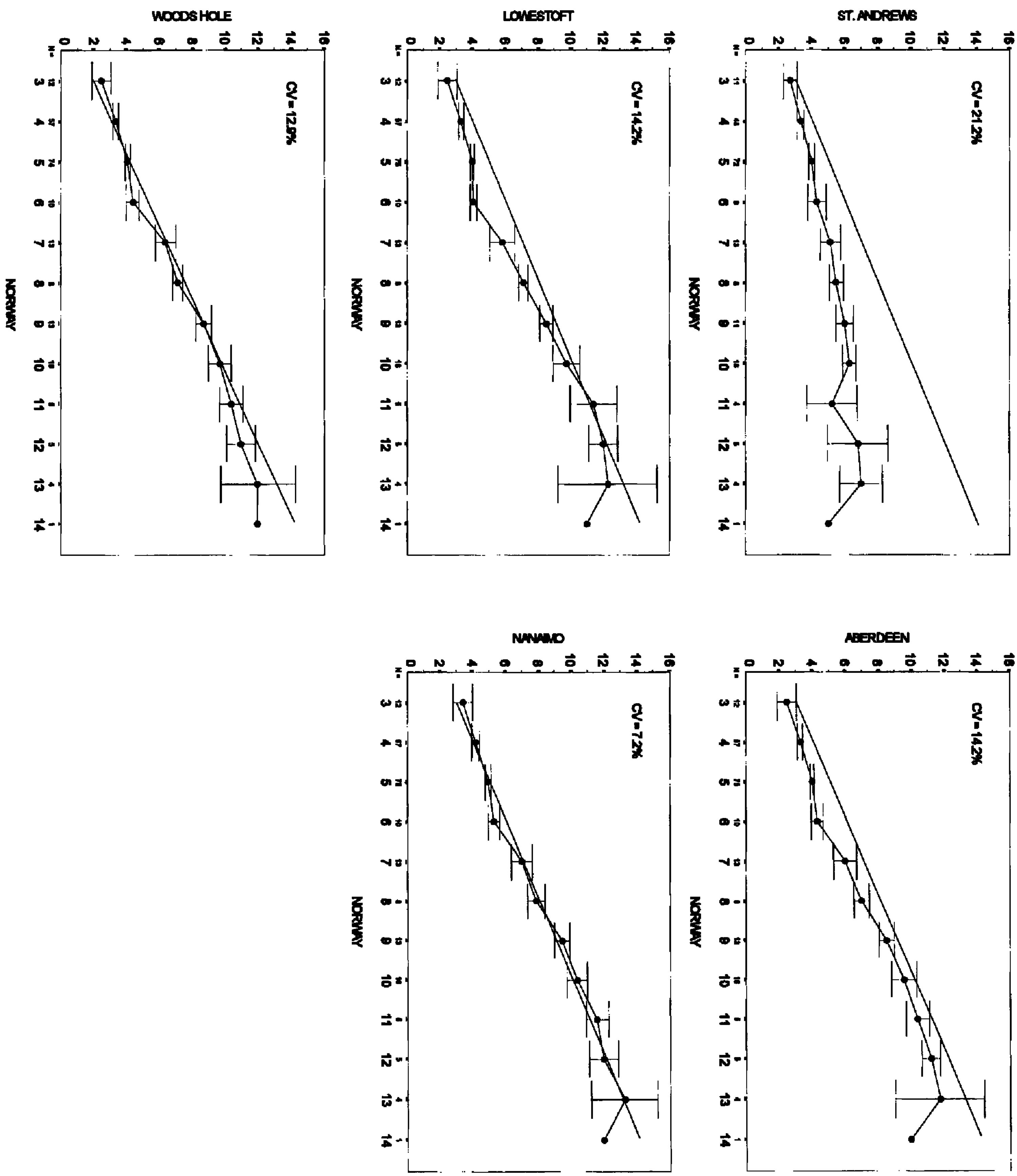

Fig. 2f. 4X ages in comparison with those of Norway.

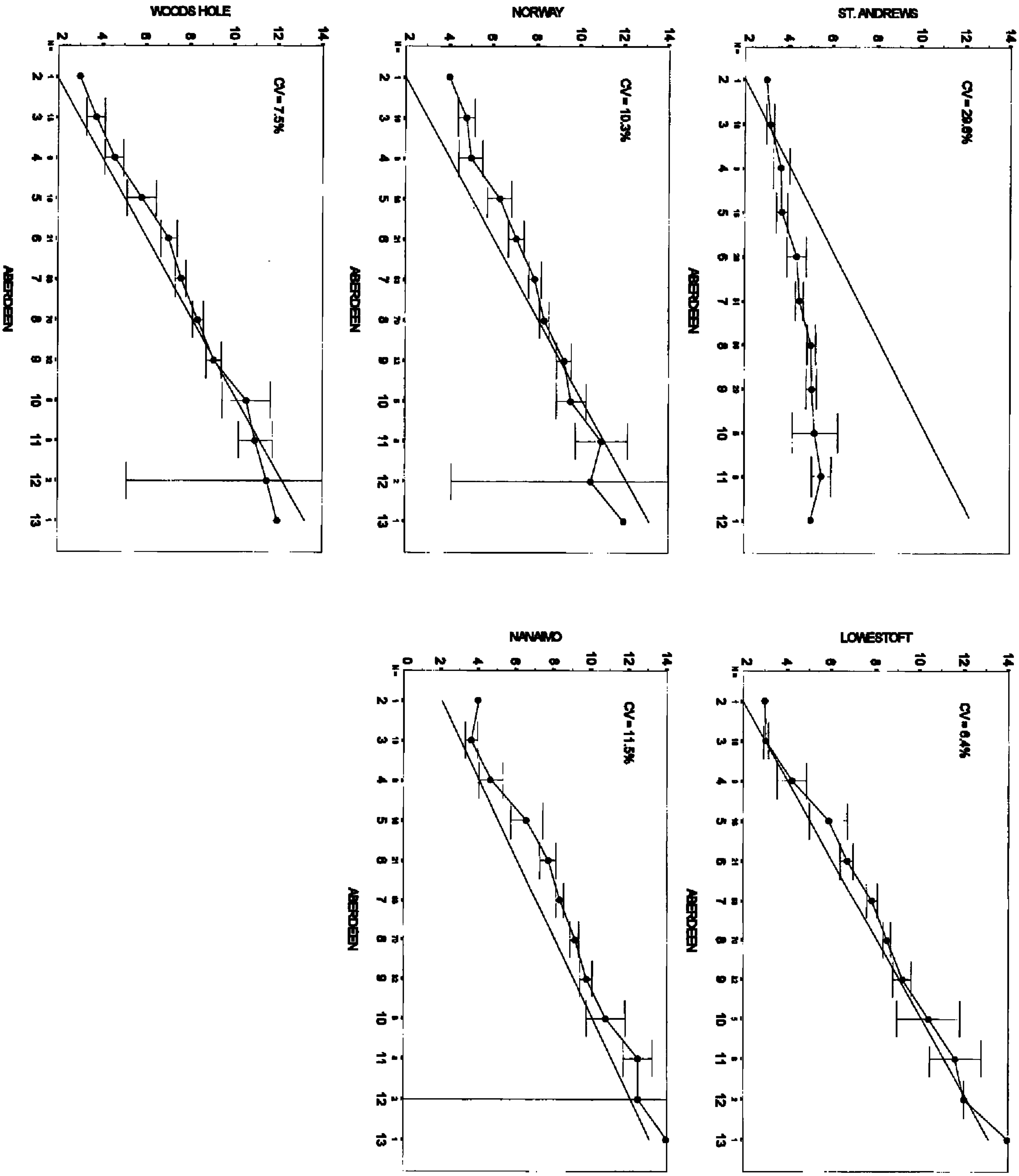

Fig. 2g. 4VW ages in comparison with those of Aberdeen.

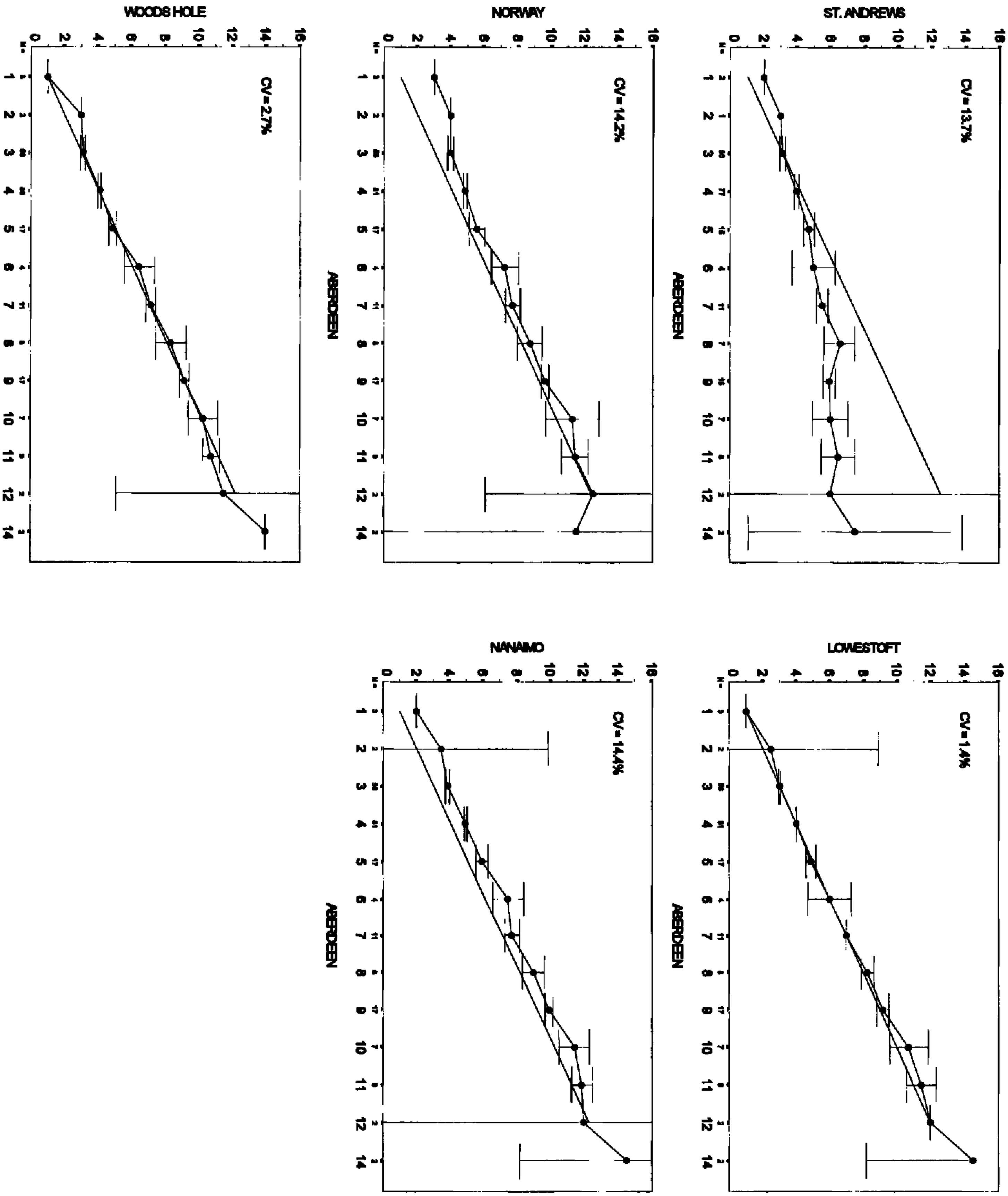

Fig. 2h. 4X ages in comparison with those of Aberdeen.

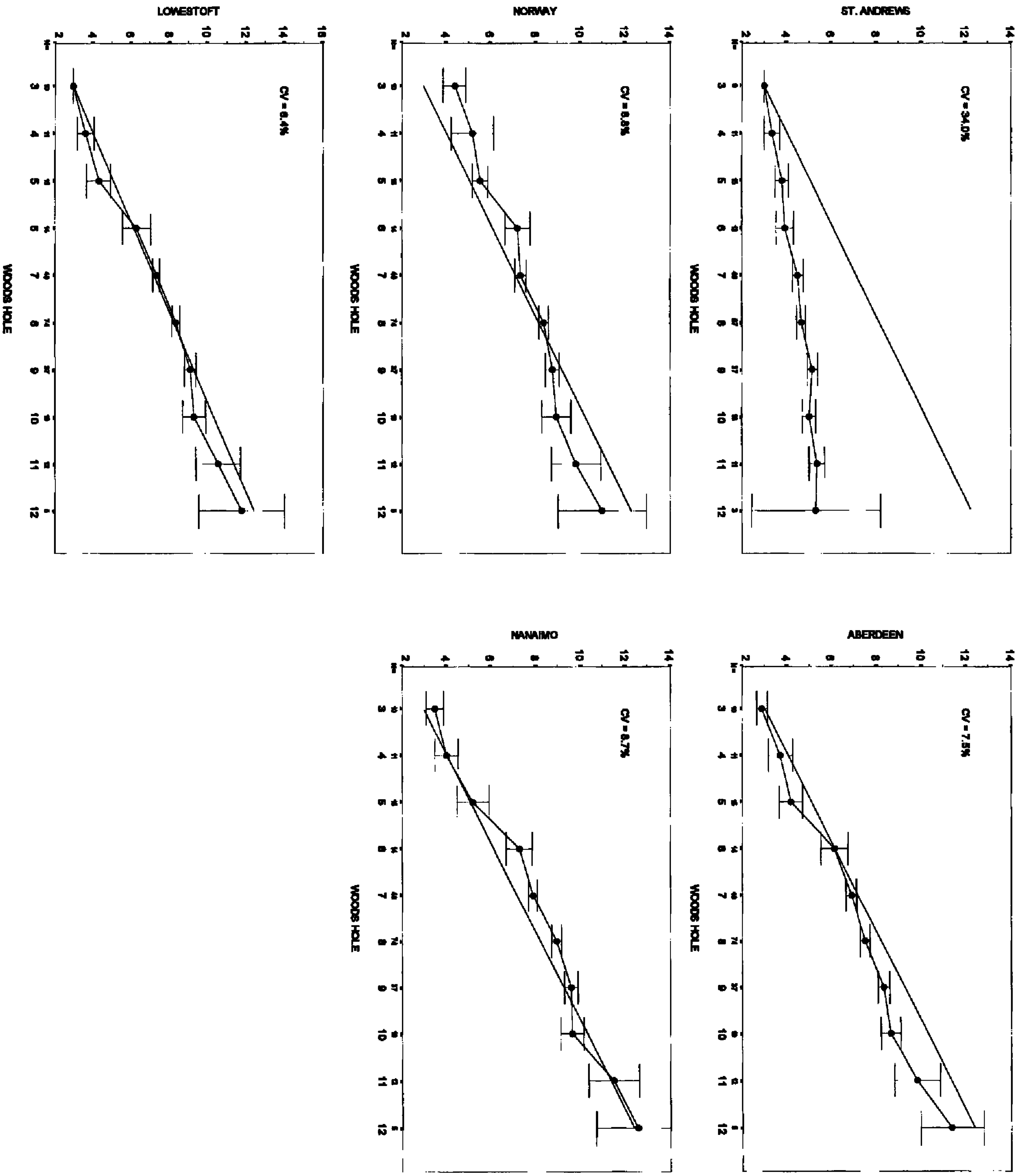

Fig. 2i. 4VW ages in comparison with those of Woods Hole.

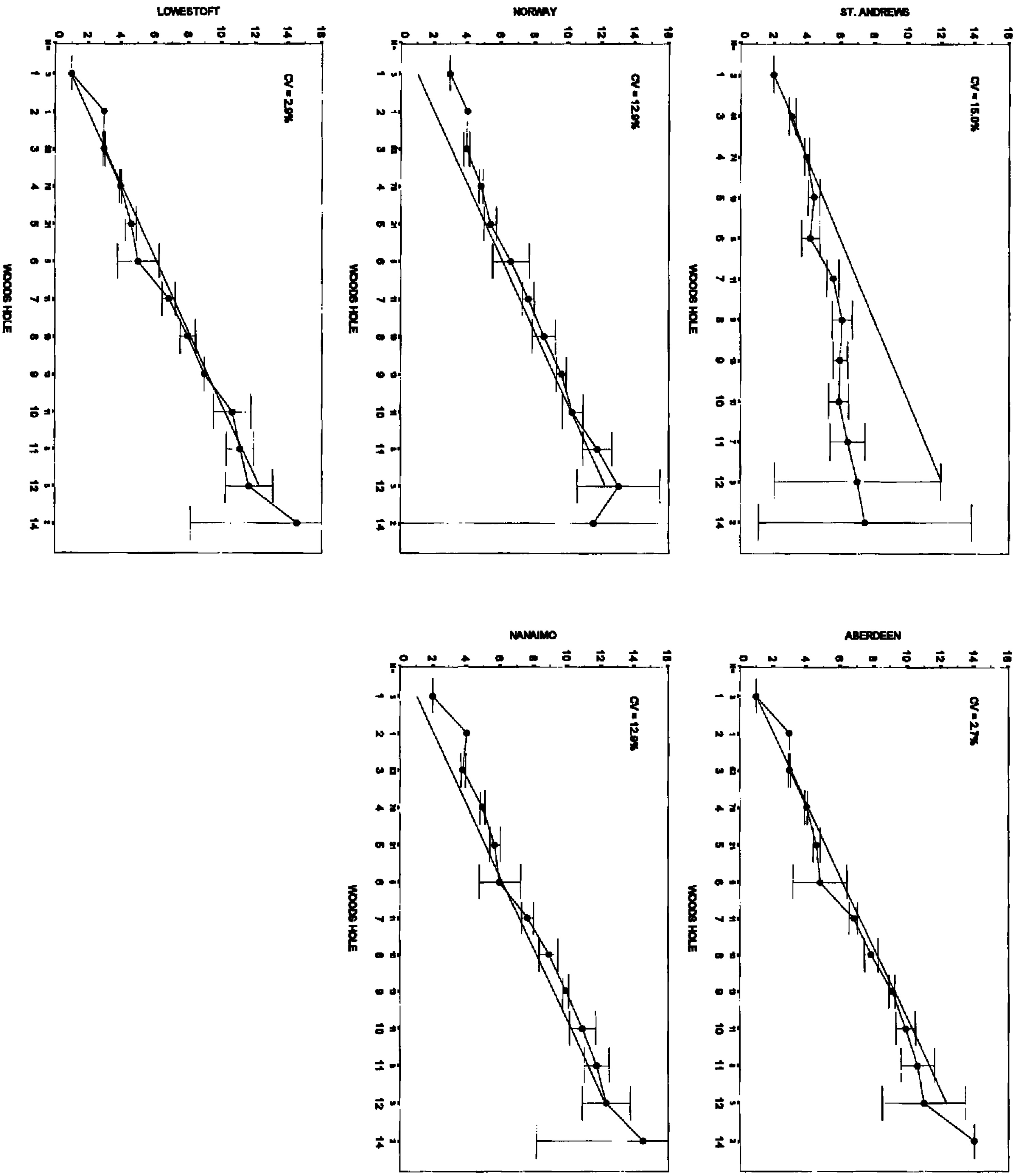

Fig. 2j. 4X ages in comparison with those of Woods Hole.

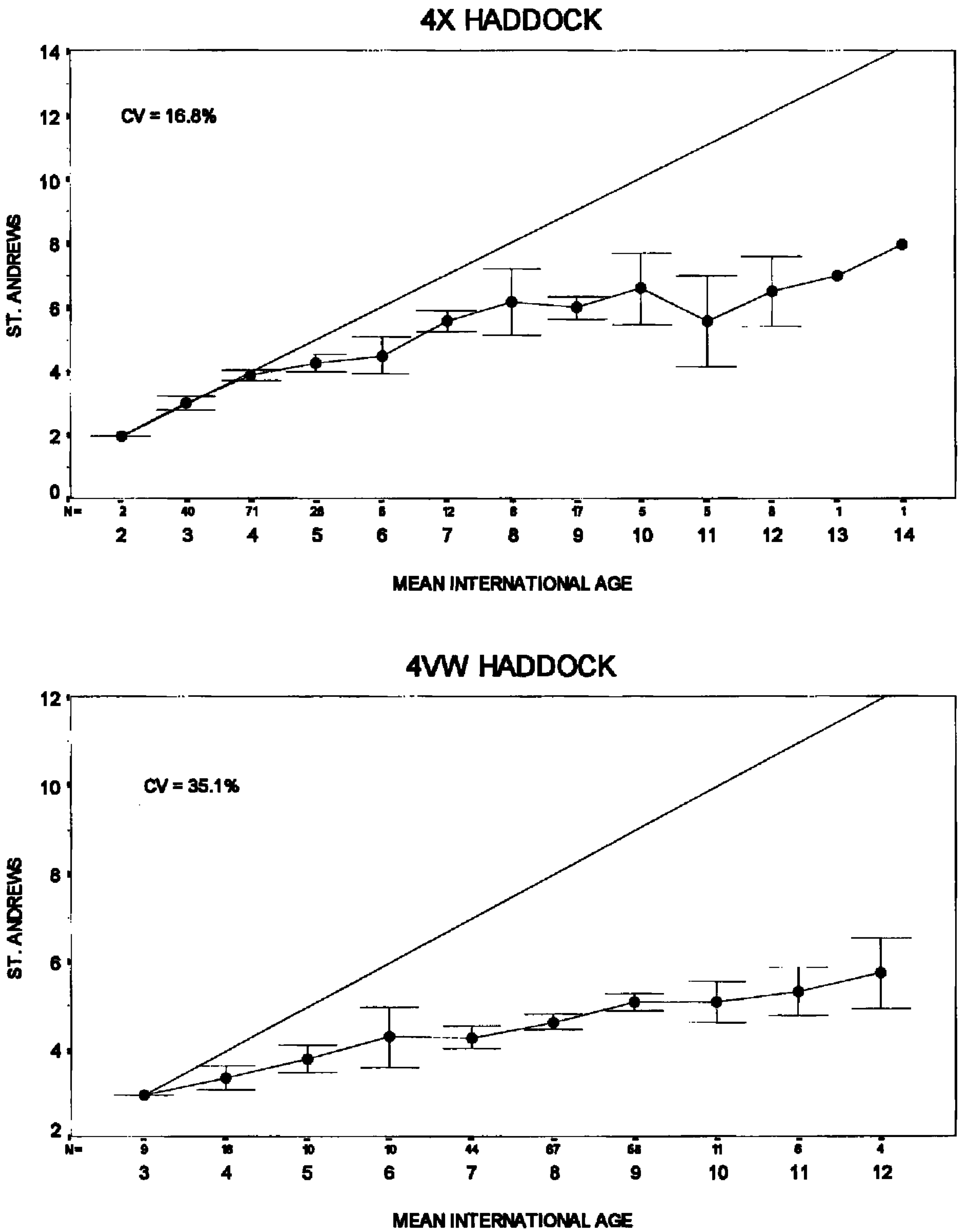

Fig. 3. Age bias plots comparing the mean rounded age of five international ageing laboratories with that of St. Andrews for the same otolith reference collection of 200 otoliths per stock. Serious bias is evident for Age 5+ for 4X haddock, and Age 4+ for 4VW haddock. For both stocks, fish aged 12 years by international standards were aged 5-7 years younger by St. Andrews.

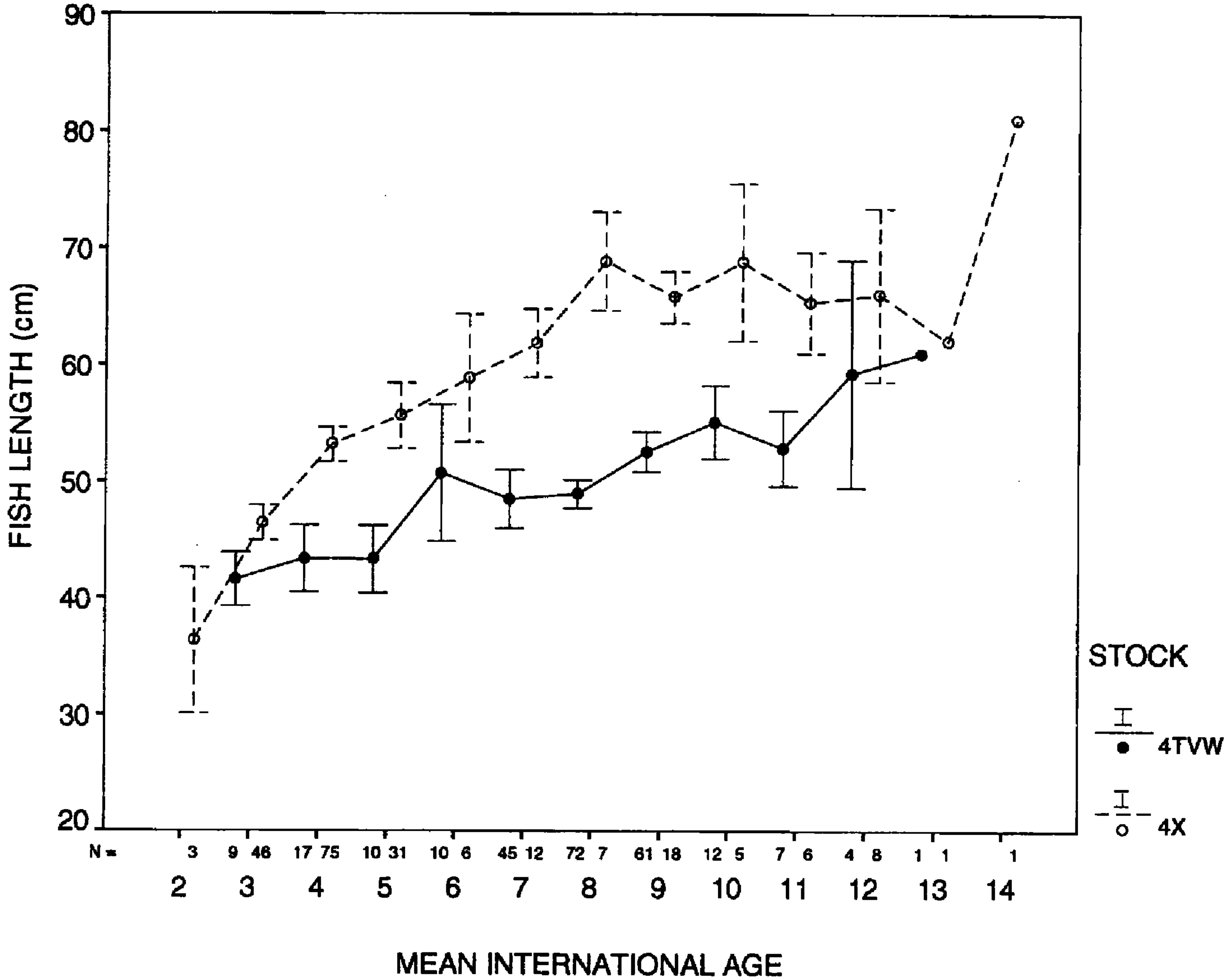

Fig. 4. Length at age for 4VW and 4X haddock in the otolith reference collections using the rounded mean age of 5 international laboratories.